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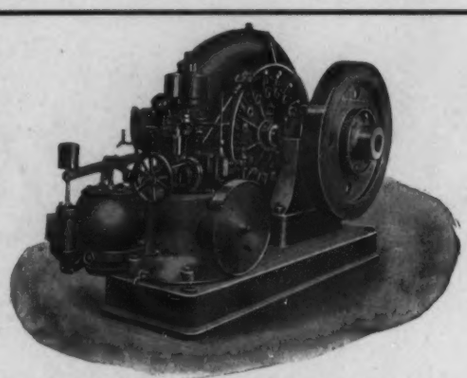

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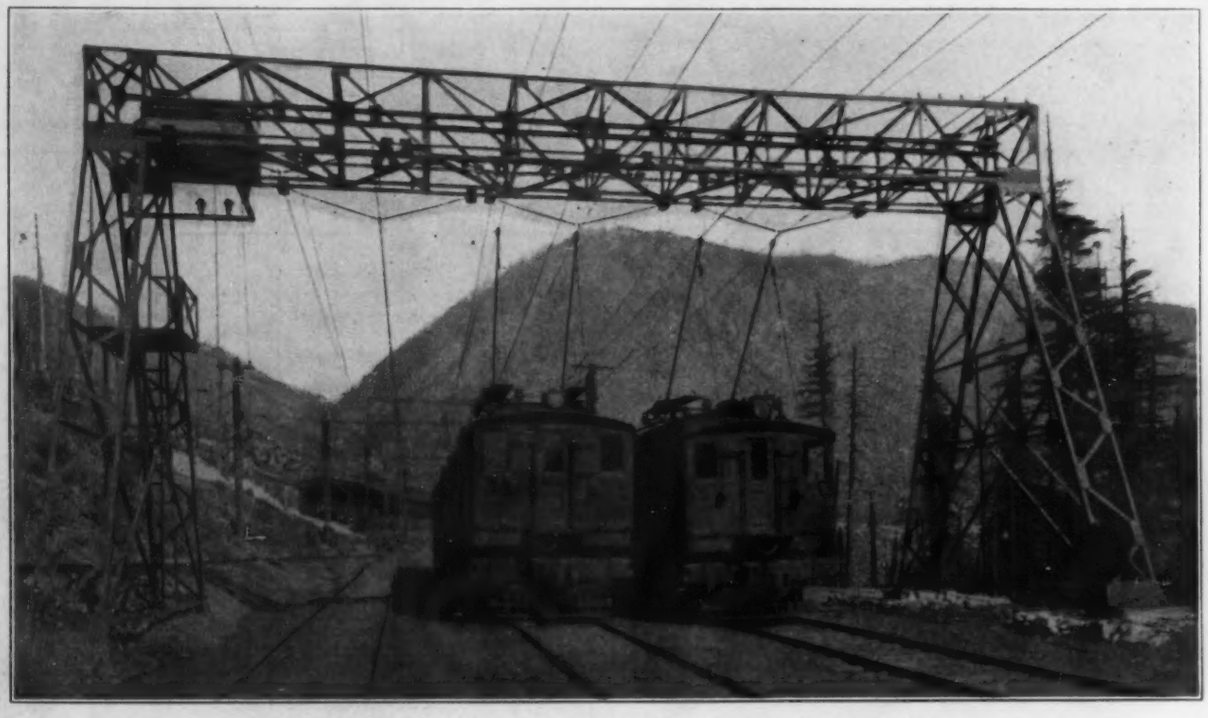
THE ELECTRIC SYSTEM OF THE GREAT NORTHERN RAILWAY COMPANY AT CASCADE TUNNEL.[1]

BY CARY T. HUTCHINSON.

The first three-phase installation on a trunk line railway in the United States was put into operation early in July of this year at the Cascade Mountain tunnel on the Great Northern Railway in the State of Washington, about one hundred miles east of Seattle.[2]



Anchor Bridge in Wellington Yard of Great Northern Electrification.

In general the plant comprises a hydroelectric generating station, operating under a head of 180 ft., having a capacity of approximately 5000 k. w. in generators at 6600 volts and 25 cycles; a transmission system operating at 33,000 volts, delivering energy to a sub-station where it is transformed to 6000 volts, at which pressure it is supplied to the overhead conductors and to the locomotive by way of an overhead trolley; on the locomotive the pressure is reduced by three-phase transformers to 500 volts for the supply of the four three-phase motors with which each locomotive is equipped.

The Great Northern Railway crosses the Cascade Mountains through a tunnel 13,873 ft. long; this tunnel is on a tangent and has a uniform gradient of 1.7 per cent; rising to the tunnel from Leavenworth, on the east, the ruling grade is 2.2 per cent, and 21 per

[1] Abstract of paper presented before the American Institute of Electrical Engineers, New York, November 12, 1909.

[2] See this Journal, July 24, 1909, for illustrated description.

cent of the total distance of 32.4 miles from Leavenworth to the tunnel is on the ruling grade. From Skykomish on the west to the summit the ruling grade is 2.2 per cent, and 44 per cent of the distance of 24.8 miles is on the ruling grade.

The operation of the tunnel with steam locomotives was at all times difficult and frequently very dangerous on account of the heat and smoke from the locomotives. In the tunnel the rails became very wet from condensed steam, and were frequently covered with a layer of coal soot and ground sand, making them very slippery. The temperature in the locomotive cab was almost unbearable, rising at times as high as 200 deg. fahr. Under ordinary circumstances it required from twenty minutes to an hour for the tunnel to clear itself of gases, but on days when the wind was changeable, the passage of the gases from the tunnel would be stopped by the change in the direction of the wind, and they would pocket. Under such circumstances, work in the tunnel was very dangerous. For these reasons this tunnel is the limiting feature to the capacity of the Great Northern Railway for hauling freight across the mountains.

Mallett compound engines are used on this division, one at the head of the train, and one pushing. The mountain section as a whole also fixes a limit to the capacity of the road, on account of the slow speed necessitated by heavy traffic; it is impossible for steam locomotives to haul heavy trains on the mountain at a greater speed than seven or eight miles per hour.

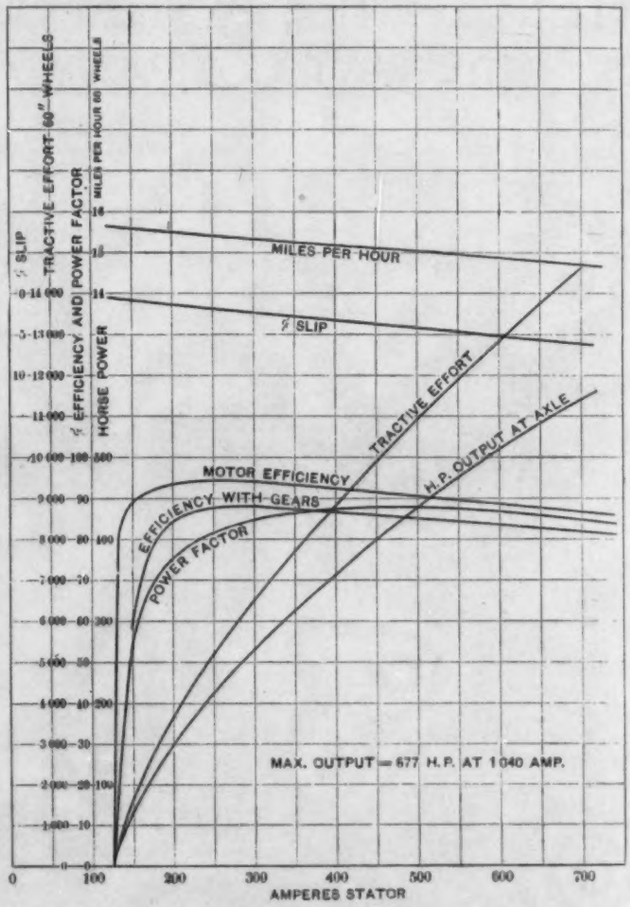
The plant described herein is designed for use over the entire mountain division, by extending the system of conductors and building additional stations; it was not designed for the operation of the tunnel alone, although even if the problem had been the handling of the traffic through this tunnel and its approaches only, the three-phase system would in all probability have been selected, on account of its greater simplicity and less cost. The choice of the system to be used was under consideration for more than a year; the three-phase system was finally decided on, plans were prepared, bids obtained, and the contract for the four locomotives let on June 22, 1907.

The original problem was to provide equipment to handle a train having a total weight of 2000 tons, excluding the electric locomotives, over the mountain division from Leavenworth to Skyknomish, a distance of 57 miles. The system was to be first tried out at the Cascade Tunnel.

The tractive effort required to accelerate a train having a total weight of 2500 tons on a 2.2 per cent grade, using 6 lb. to the ton for train resistance and 10 lb. to the ton for acceleration, making a total of 60 lb. to the ton, is 150,000 lb.; this would require four locomotives of a tractive effort of 37,500 lb. each. The railway company's engineers limited the weight on a driving axle to 50,000 lb.; therefore four driving axles per locomotive are needed, giving a coefficient of adhesion of about 19 per cent. This is a measure of the maximum power required. The locomotive was, therefore, designed to give a continuous tractive effort of approximately 25,000 lb., and it was expected that four would be used with a train maximum weight. But the locomotive as built greatly exceeds this specification.

Design of Locomotive.

The principal data of locomotive are as follows: total weight 230,000 lb. all on drivers; two trucks connected by a coupling, each truck having two driving axles; a three-phase motor connected by twin gears to each axle; gear-ratio, 4.26; diameter of driving wheels 60 in.; synchronous speed of motor 375 rev. per min. giving a speed of 15.7 miles per hour at no load, dropping to 15 miles per hour for a load corresponding to the one-hour rating. The motors are wound for 500 volts and are completely enclosed and air-cooled; clearance between stator and rotor, 1/8-in.; trolley pressure, 6000 volts; each locomotive has two three-phase transformers reducing the pressure from 6000 to 500 volts, arranged with taps so that 625 volts may be used on the motor.



Characteristic Curve of Great Northern Three-Phase 475 h. p., 25 Cycle, 500 Volt Motor.

The specification of the motor required an output of 250 h. p. continuously for three hours with 75 deg. cent temperature elevation, when supplied with not more than 2000 cu. ft. of air per minute. The test results of the motor show a continuous output of 375 h. p. at 500 volts with 1500 cu. ft. and 400 h. p. at 625 volts, with the same air; the one-hour rating of the motor at 500 volts with 1500 cu. ft. of air per minute is 475 h. p.; the ratio of continuous output to the hour-rating with 1500 cu. ft of air is therefore 79 per cent. The continuous output at 500 volts corresponds to a tractive effort of 9350 lb. per motor and the one-hour output to a tractive effort of 11,900 lb. per motor;

the locomotive will, therfore, give 37,400 lb. tractive effort in continuous duty, or 47,600 lb. tractive effort for one hour.

The locomotive has been tested to a maximum tractive effort of nearly 80,000 lb., corresponding to a coefficient of adhesion of nearly 35 per cent; with 60,000 lb. or 26 per cent, each locomotive can accelerate the train of 885 tons trailing on a 2.2 per cent grade, using 60 lb. per ton as the total tractive effort; or, in other words, the train that a locomotive can haul, as determined by the average duty and safe heating limits, is just about equal to the train that it can accelerate on the maximum grade; that is, the average capacity of the locomotive and its maximum capacity are in the same proportion as the average duty and maximum duty. The design is well balanced.

Making some allowance for these figures for the sake of conservatism, the rating of the locomotive on this division can be put at 750 tons trailing load.

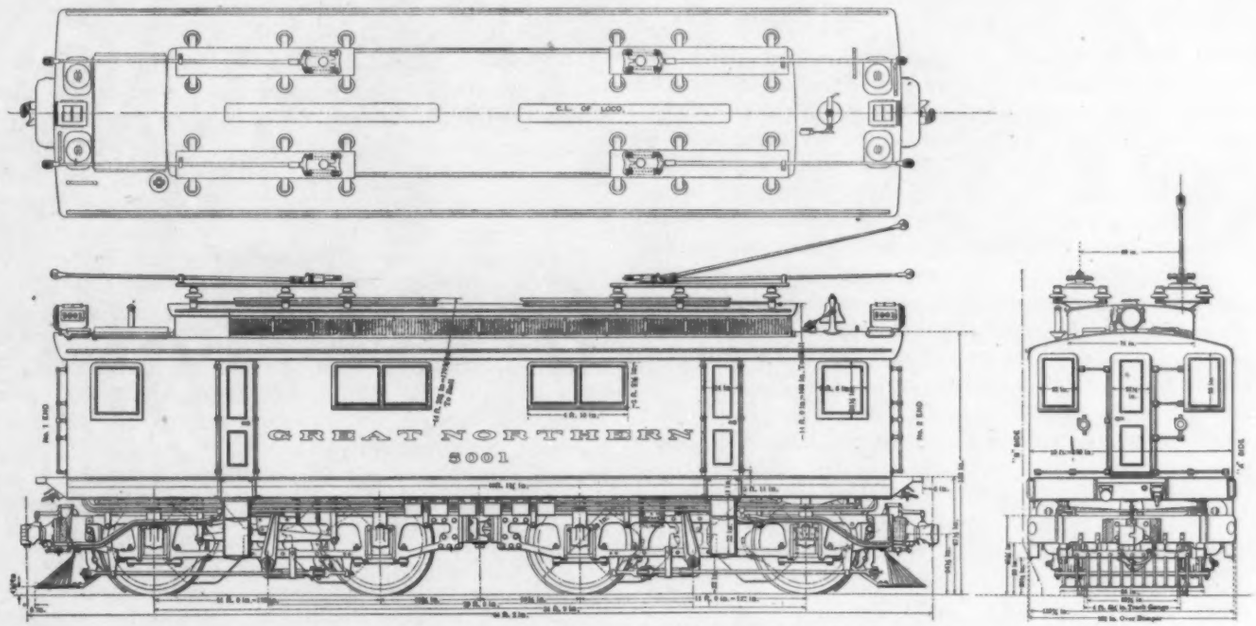
Compressed air for the brakes is supplied by 100 cu. ft. induction-motor-driven compressors; the cooling air is supplied by a 9400-cu. ft. motor-driven blower. The locomotive is equipped with a combined straight and automatic air-brake system.

The control system of each motor is separate; the circuits branch from the transformer and are independent through the resistances. There are 14 contactors in each motor circuit, 56 in all. The pilot control is in duplicate, one switch at each end of the locomotive. There is a clear aisle on each side of the locomotive from end to end, all of the apparatus being assembled in the center of the cab.

At first I intended to have two running speeds by changing the number of motor poles, but this led to many complications; every effort was made to keep the equipment as simple as possible, and I finally decided to use resistance control in the rotor of the motors and to have a single-speed unit.

Iron grid resistances are provided for each motor; there are thirteen steps in the control, but in order to reduce the number of contactors to the lowest possible point an unsymmetrical system is used. A change is made in the resistance of one phase only, in passing from step to step. This arrangement in effect treats the three-phase circuit as a single-phase circuit; on each step of the control the torque is the average of the three values of the torque of the separate circuits. The principal advantage of this is that 56 contactors do the work that would otherwise require 128, thus effecting a great gain in the simplicity of the control apparatus.

Experience with the locomotive in service indicates that the initial torque, which is approximately 20,000 lb., is somewhat high, and I am now having the control changed so that on the first step two motors only will be thrown in circuit, and on the second step all four motors. This change is readily made by eliminating step 12, which tests have shown to be of little or no value.



General Dimensions of Great Northern Three-Phase Electric Locomotive.

The locomotive is of the articulated or hinged type, having four driving wheels on each half of the running gear and is without guiding wheels. The running gear is not two independent trucks coupled together, but is more nearly comparable to the Mallet type of steam locomotive, in that the hinged sections are so rigidly connected that they tend to support each other vertically and guide each other in taking the curves, although the hinges are designed to offer minimum resistance to lateral flexure. There are no springs to prevent this flexure, and the wheel base is free to accommodate itself to any curvature; the effect of this guiding action is to minimize the flange wear, as in the Mallet locomotive.

The cab extends the entire length of the platform and is made of No. 10 steel plates which carry a monitor that supports the trolley base and has a ventilated opening running through the centre and perforated side plates to permit the escape of air from the

interior of the cab. The greater part of the control apparatus, the rheostat, the transformers, contactors, etc., is placed in a separate compartment 60 in. wide and 22 ft. long, enclosed by steel partitions extending directly up to the monitor roof. This leaves two open operating spaces at the ends of the locomotive, connected together by two side aisles 30-in. in width. This centre compartment is divided into three parts by steel-plate partitions, the middle part contains the high-tension apparatus, including switchboard; the end parts are duplicates, each containing one transformer and the contactors for two of the motors. The rheostats are placed in the monitor at the top of the cab. The air for ventilation, after passing through the transformers, cools the rheostats and then escapes to the atmosphere. Placing these rheostats at the top of the cab has also the advantage of raising the centre of gravity of the locomotive, which is nearly 60 in. above the rail head, higher than is usual with electric locomotives.

Generating System.

The energy supply for the locomotive is derived from the Wenatchee River, which flows along the line of the railway for a distance of some 20 miles. The power house is located about 2.5 miles west of Leavenworth. There is a low concrete diverting dam in the river at a point about 12,000 ft. west of the power house, and from this dam a wood-stave pipe of 8.5 ft. interior diameter runs for a distance of 10,908 ft. and continuing this stave-pipe line is a steel-pipe line for a distance of 962 ft. The pipe line has substantially the same gradient as the railway line, and gives a static head at low water of 203 ft. and in ordinary water of about 200 ft. The operating head at rated load is 180 ft.

The crest of the diverting dam is 400 ft. long; it has three head gates, a log sluice and a fishway. The pipe line ends in a surge tank at the corner of the power house, having a total height of 183 ft. above its foundation. The tank proper is 30 ft. in diameter, and with a storage height of 54 ft. above its hemispherical bottom gives a storage capacity of approximately 38,000 cu. ft.

The pipe line leads directly into the upright pipe of the surge tank, which is 8 ft. in diameter; within the upright pipe is a waste pipe having a diameter of 3 ft. 2 in., extending 7 ft. above the level of the crest of the dam; in the tank the waste pipe is expanded uniformly to a diameter of 7 ft. 6 in., thus affording a circular weir of 23.5 ft. in length.

The power house is designed for three main units and two exciter units. There are now installed in the power house two main units, each turbine rated at 4000 h. p., directly connected to a three-phase alternating current.

The two main units now erected, with the exciter, require approximately 500 cu. ft. of water per second when operating at full load of 8000 h. p., giving a velocity of flow in the penstock of 8.7 ft. per sec.

The extreme low flow of the river at the dam is estimated to be 380 sec-ft. The small pond formed by the dam has a storage capacity equivalent to 8000 h. p.-hr., for a depth of one foot: it is possible to draw the water in the dam down three feet. There are two other power sites in the canyon, each affording a head of 200 ft., available for subsequent developments.

The entire hydraulic installation was designed and constructed under the direction of J. T. Fanning of Minneapolis.

The electric equipment in the power house at present consists of two main generating units, each for a nominal capacity of 2500 kilovolt-amperes at 375 rev. per min., 6600 volts and 25 cycles; these machines are designed to have very large overload capacity, and operate at a low flux density.

There are two exciter units, each having a nominal capacity of 125 kw. at 750 rev. per min. These units also have a large overload capacity; they frequently carry 150 per cent overload, on account of the very poor regulation of the water wheels. A third unit, identical with the first two, has been ordered.

The power house also contains four transformers for raising the pressure to 33,000 volts, each of a nominal capacity of 833 kw. but guaranteed to operate 100 per cent overload for one hour, with a low rise in temperature. Three of these units are in service, the fourth is kept as a spare.

The switchboard apparatus is of the usual type, having panels for the generators and the feeders, and is provided with the usual measuring instruments.

One reason leading to the use of the three-phase system was the possibility of regeneration; that is, of returning energy to the system on down grades. With the present installation it is obviously not possible to make any use of the energy so returned, but in order to prove this practically an automatic rheostat controlled by the speed of generator was installed in the power house; when a train on the down grade reaches a little more than the synchronous speed, the electrodes of the water rheostat are automatically lowered by an amount proportional to the difference between synchronous speed and the speed of the generator; this throws a load on the system and acts as a brake to the train. The operation of this apparatus is entirely effectual.

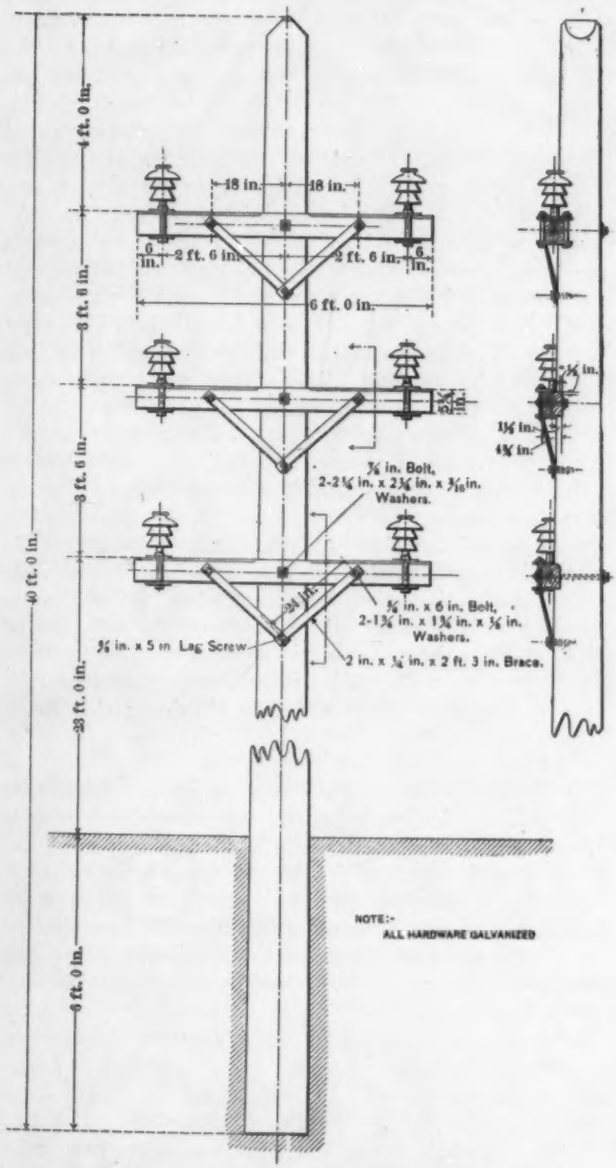
The nominal capacity of parts of this equipment, in particular of the transformers, may seem unusual; but it must be remembered that the plant is intended to operate on a load having extreme fluctuations, the entire load being on for, say, 15 minutes and then off for two or three hours, and consequently the transformers can be made small.

This plant has operated satisfactorily with the exception of certain troubles with the water wheels; in particular, the generators have shown ability to hold their rated pressure under extreme variations of speed, due to the effective control of the Tirrill regulators. The generator fields, designed for 125 amperes, have frequently carried 300 to 350 amperes, and the regulators have held the pressure normal, in spite of fluctuations of 35 to 40 per cent in speed.

Transmission Line.

The transmission line extends from the power house at Leavenworth to the sub-station at Cascade, a length of approximately 30 miles, following the railroad all the way; part of the distance it is on the same side of the river as the railroad and part of the opposite side.

The line carries two circuits each of No. 2 B. & S. gauge stranded hard-drawn copper wire; each circuit is in a vertical plane at one side of the pole, thus permitting the use of short cross-arms; the upper cross-arm was placed some distance below the top of the pole in order to leave room for a ground wire, which has not as yet been installed. The poles are


18 in.
18 in.
6 in.
2 ft. 6 in.
2 ft. 6 in.
6 in.
6 ft. 0 in.
4 ft. 0 in.
8 ft. 6 in.
8 ft. 6 in.
40 ft. 0 in.
23 ft. 0 in.
6 ft. 0 in.
¾ in. Bolt, 2-2½ in. x 2½ in. x 5/16 in. Washers.
¾ in. x 6 in. Bolt, 2-1¾ in. x 1¾ in. x ⅜ in. Washers.
⅝ in. x 5 in. Lag Screw.
2 in. x ¼ in. x 2 ft. 3 in. Brace.
1½ in.
4½ in.
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Standard Pole of Transmission Line: two 33,000-volt circuits of No. 2 B. & S. gage wire

40 ft. long, placed 6 or 7 ft. in the ground, the tops being 10 in. to 12 in. in diameter; these poles are usually sturdy, and it was owing to the fact that timber of this kind could be obtained cheaply in the West that this type of construction was adopted. The line is divided into three sections by two out-of-door switches operated by means of a pole deposited with a station agent; each switch is near a station.

In the design of the line, as in all other features of the work, the aim was to secure apparatus and types of construction giving promise of the greatest reliability, in order that there should be as few links as possible in the chain from the power house to the locomotive that would be liable to derangement; for this reason a comparatively low line pressure is used.

The telephone line is carried on the same poles; the transmission line is not transposed, but the telephone line is transposed at every fifth pole.

The construction of this line was completed a year ago, and it has stood through one winter, during which there were more than thirty snow and rock slides; only one of these slides caused damage to the line, and in this case only one of the two circuits was interrupted; it could have been repaired within an hour. The same slide interrupted the operation of the railroad for eight or ten hours.

The sub-station is at Cascade, practically at the east portal of the tunnel. Three single-phase transformers are in service and a fourth in reserve; these transformers are duplicates of those in the power house. The equipment of the sub-station is along the usual lines and calls for no special comment. The low pressure bus-bars at the sub-station are connected to the overhead wires in the Cascade yard and also to the Wellington feeder, which runs through the tunnel to the extreme end of the Wellington yard.

Overhead Construction in Yards.

Bracket and cross-catenary construction was used in yards. The wires are 24 ft. above top of rail and 5 ft. apart; for single tracks a bracket type of construction is used, and for multiple tracks a cross-catenary type, supported by very heavy wooden poles located about 8 ft. from centre-line of outer tracks, thus leaving unobstructed the space between adjacent tracks. The wires are supported at intervals of 100 ft.

Multiple track supports consist, for each phase, of a steady span supported by and insulated from a cross-catenary span, both spans being secured to cross-arms on the poles by means of porcelain petticoat strain insulators; the spans for the two respective phases are three feet apart. The wires of the same phase, for the different tracks, are insulated from each other by means of wood breaks and porcelain link insulators, in series.

In the case of brackets, each phase is insulated from ground by means of a wood break in series with a porcelain petticoat strain insulator.

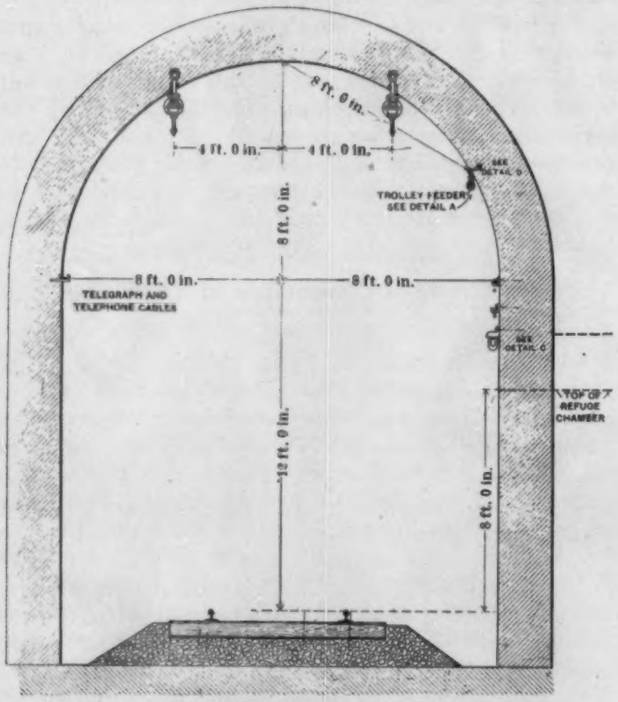
Where wires of opposite phases cross at turnouts, they are insulated from each other by section insulators made of wood and about five feet in length; four insulators are used, each connected at one end to a special 8-deg. crossing pan and at the other end to one of the four wires converging toward the crossing. Except for one track whose wires are cut straight through the crossing pans without section insulators, it is necessary to switch the controller to the off position when the trolley wheel passes under the insulators; methods of avoiding this have been considered and are being tried out.

Heavy steel bridges, forming anchorages for the trolley wires are located in both yards at intervals of 1000 ft. Lightning protection, though thunder storms are rare, is afforded by arresters connected to the wires at the ends of the tunnel and yards.

Both rails in the tunnel and one rail in the yards are bonded, with cross-bonding at frequent intervals.

A single 4/0 exposed bond is used at each joint, having a length of 36 in. in the tunnel, and 36 and 50 in. in the yards.

It is my opinion the use of double insulation everywhere is the reason for the almost total freedom from troubles of any kind originating on the overhead structures; two separate pieces of insulation of any given strength are much better than one piece of four times that strength. The only troubles experienced up to the present have been at the section breaks and turn-outs, and have been caused by the trolley wheel leaving the wire. There has been no failure of the wires at any point of the overhead structure nor any breakdown of insulation.



Cross-Section of Cascade Tunnel, showing Location of Trolley Wires, Trolley Feeder, Lighting and Telegraph Cable.

In the tunnel the wires are 17 ft. 4 in., above the top of the rail and 8 ft. apart; the latter spacing enables trainmen to operate the hand-brakes, or walk on the tops of freight cars, the construction being such that head-room is not interfered with. Each wire is supported every 50 ft. by means of a 14-in. Detroit clamp attached by swiveled connection to a stud which is in turn swiveled to the middle point of a turnbuckle. The two eyes of the latter, by means of strand wire, connect each to a link and petticoat strain insulator arranged in series, the two petticoat insulators being secured to the roof of the tunnel by means of two expansion bolts, about 5 ft. 6 in. apart. Anchors and side-braces for the wires in the tunnel are located at intervals of 3000 ft.

Practically all metal work in the tunnel supports is copper or bronze, but experience has shown that galvanized iron, soon becoming protected by a slight coating of soot, would have been satisfactory. The insulators, when first put in service, were covered by a very thick coating of wet soot, but, even under these conditions, it was found possible gradually to bring the voltage up to normal without breakdown. Volumes of smoke and steam issuing from steam locomotives caused only a slight surface leakage, and one rough cleaning sufficed to put the insulators in reliable working condition.

Spacing the wires 8 ft. in the tunnel was necessitated by the requirement of the railroad company that there should be no construction in the roof of the tunnel which could possibly interfere with a brakeman's walking on the top of a freight car. This change in the location of the wires complicated the construction somewhat and was one of the principal reasons leading to the use of a trolley wheel in place of a bow collector. It has, however, caused no material inconvenience and is satisfactory as long as the trolley wheels are in use, but if a change is made to a bow collector, which is not impossible, there may be difficulty in adapting the bow to this location of the wires.

It is intended ultimately to clean and whitewash the tunnel and light it electrically, and for this purpose a lighting system has been installed. Five transformers of 4 kw. capacity each are placed in refuge chambers; incandescent lights are spaced 50 ft. apart and are connected five in series of a 500-volt system. Several plans were worked out for this lighting system, but taking into account maintenance costs, it seemed best to use a standard 110-volt carbon filament lamp.

Telegraph wires, ten in number, run through the tunnel in a cable; this service was thrown entirely out of commission when the electric locomotives began running. There is no interference with the telegraph wires due to the transmission lines paralleling them for thirty miles; the entire interference seems to originate in the tunnel. In order to eliminate this interference, a neutralizing transformer has been installed and adjustments are now in progress. There has been little difficulty in making the ordinary single-wire telegraph service satisfactory, but considerable difficulty has been experienced in getting the quadruplex to work satisfactorily; this matter is still unfinished.

The electric service was started on July 10, although one or two trains had been handled previously. From that time to August 11, practically the entire eastbound service of the company has been handled by electric locomotives.

During this period of 33 days there have been 212 train movements of which 82 were freight, 98 passenger and 32 special. In each case the steam locomotive was hauled through with the train.

The tractive effort for the passenger trains varies from 40,000 to 50,000 lb., depending on the number of steam locomotives taken through; two electrics are ordinarily used, although one would answer in nearly all cases.

During this period there have been no delays due to failure of the electric locomotives, and but two trifling delays due to failures of the electric plant, both chargeable to the transmission line and both caused by accidents beyond the control of the operating force.

On Augut 11 the electric service was discontinued, owing to failure of both water wheels. Service was resumed on September 9 and has been continued regularly since. The plant was taken over by the operating department of the railroad late in September.

The westbound service was not at first handled by the electrics regularly, as there is nothing in particular gained by braking the trains electrically on this short stretch, but now westbound passenger trains are so handled, for the benefit of the passengers.

A number of tests have been made to determine the power returned when regenerating; the following is typical:

TRAIN: MALLET ENGINE, 1550 TONS CAR WEIGHT, TWO ELECTRICS ON 1.7 PER CENT GRADE.

Force due to grade.	Frictional Resistance.	Remainder for acceleration.
Mallet ..... 8,500 lb.	11,500 lb.	— 3,000 lb.
1550 tons in cars .....52,500 lb.	9,300 lb.	+43,200 lb.
Three electrics .....11,700 lb.	2,070 lb.	9,630 lb.
Total for acceleration .....49,830 lb.		

This is equivalent to 1495 k. w. delivered to the gears of the motors at 15 miles per hour.

The efficiency of the locomotive is approximately 80 per cent—hence the power returned to the line, should be 1200 k. w. The test of this train gave 950 k. w.; this difference is due to the standard practice, not yet abandoned, of keeping a certain number of car pressure retainers set on down grade.

The Mallet, instead of adding to the delivered power is an additional load that has to be carried by the train.

A similar test on a ten-car passenger train weighing 950 tons gave

Delivered power, calculated	590 kw.
Delivered power, measured	597 kw.

In this case there was no added resistance of pressure retainers.

These tests merely confirm the calculations, as they should. On a 1.7 per cent grade, then, one ton, descending at 15 miles per hr., will deliver 0.67 k. w. to the system; on a 2.2 per cent grade it will deliver 0.91 k. w.

The losses in the system when delivering 4000 k. w. to the locomotive, at the west end of the Wellington yard are:

Place.	Power Kilowatts.	Per cent.
Power house low tension bus-bars	4740	100
Sub-station low tension bus-bars	4250	89.8
Trolley wheel of the locomotive	4000	84.5
Driving axles of the locomotive	3320	70.

The average efficiency is somewhat higher than 70 per cent.

Handling of Trains.

The maximum duty was imposed upon this equipment from the outset. On account of very poor regulation of water wheels, steam has been used in one of the Mallet engines in starting the freight trains in the Wellington yard; an attempt has been made to use just sufficient steam to enable the Mallet engine to turn itself over. Steam is shut off at the portal of the tunnel; in addition to this, in order to provide smoother starting, a slight air pressure has been maintained on the locomotive at starting, which is gradually reduced.

On several occasions trains have broken in two, due to the trolley wheel on the rear locomotive leaving the wire and thus cutting off part or all of the power supply to the rear locomotive. This throws a greatly increased draw-bar pull on the front locomotive, and the consequence is that the train is jerked apart. This happened in the early stages of the work, and was due to the fact that the turn-outs were not in the best order, and also that the engineers had not sufficient experience in handling trains. Another means taken to avoid the broken draw-bars was to use the rear Mallet engine to assist the train over the trolley crossings in the Wellington yard; this was a temporary measure and has been discontinued.

A modern steam station can deliver one kilowatt-hour for 3 lb. of coal, at the bus-bar, which, with an efficiency of 70 per cent to the rail, gives a consumption of 4.28 lb. per kilowatt-hour at the rail. The Mallet compound requires nearly twice as much coal per kilowatt-hour at the rail as would be used in a modern steam station in the place of the hydroelectric station at Leavenworth.

Advantages of Three-Phase System.

This plant has demonstrated, in my opinion, that the three-phase induction motor has certain very marked advantages over any other form of motor for heavy traction on mountain grades; these advantages may be stated somewhat approximately.

1. **Maximum electrical and mechanical simplicity.** This point is of great importance and was one of the principal reasons for using three-phase system; the motors will stand any amount of abuse and rough use.

2. **Greater continuous output within a given space than can be obtained from any other form of motor.** This, I believe, is shown by comparison with other electric locomotives; it is due to the fact that the losses can be kept lower in a three-phase motor than in any other type. As Fig. 3 shows, the electrical efficiency of the motor is high for a wide range of load.

3. **Uniform torque.** This is important, particularly at starting. I believe that a three-phase motor will work to a three or four per cent greater coefficient of adhesion than a single-phase motor at 15 cycles.

4. **The possibility of using 25 cycles.** This is important, as it leads to a less cost and a better performance of power station apparatus; moreover, it is standard and the power supply can readily be used for other purposes, as well as for traction; a commercial supply can be provided.

5. **Constant speed.** This is ordinarily stated as a disadvantage of the three-phase motor; but in my opinion it is a distinct advantage in mountain service, particularly the limitation of the speed on down grades. It has also the advantage on up grades that meeting points can be arranged with greater definiteness. There is a general notion that the impossibility of making up lost time with the three-phase motor will be a decided drawback to its use. This would be true if there were the same liability to lose time with three-phase motors; but when a train can be counted on to make a definite speed, without regard to conditions of tracks or of its load, there is less liability to lose time. Although I am not prepared to state that a three-phase

motor is suitable for cases where the profile is very variable, yet it is by no means certain that it would not work out well; the question is merely one of making a given schedule between two points with greatest regularity.

6. **Regeneration on down grades.** This matter has been discussed since the earliest days of electric traction, but, as far as I know, has not been, up to the present, put into practice. Although this result can be attained with other forms of motors, yet it is most perfectly attained by three-phase motors, there being no complications involved. This is of importance in reducing the power-house capacity required for a given service, although, no doubt, the saving in power-house capacity will not be as great as indicated by theory, owing to the various emergencies that must be provided for, nevertheless there will be a material saving. A 2500-ton train on the average down grade of 1.5 per cent will deliver about 1400 k. w. to the system. The equivalent power house capacity would cost at least $200,000; hence if only 20 per cent of this can be utilized the saving will equal the cost of one locomotive.

7. **Excessive short-circuit current is impossible and** consequently destructive torque on the gears and driving rigging is eliminated. There will be no necessity for the complication of a friction connection between the armature and driving wheels, as in the design of recent large direct-current electric locomotives.

8. **Impossibility of excessive speeds.** Even when the wheel slips the speed remains constant. Therefore, the maximum stresses put on the motor are less and are more accurately known than with any other form of motor.

Disadvantages of Three-Phase.

On the other hand, the principal disadvantages of three-phase motor, for traction use, are commonly stated to be:

1. **The constant speed.** This is rather an advantage for this class of service.

2. **Constant power.** The fact that the motor is a constant-power motor and therefore requires the same power at starting and while accelerating as at full speed. While this is true, it is not a matter of any particular consequence in a service where the stops are very few, and consequently the proportion of total time spent in acceleration is small, and where the additional power required to accelerate the train is a small percentage of the power used by the train at full speed. In this particular case on the 2.2 per cent grade, when accelerating at the rate of 10 lb. to the ton, the power required during acceleration is only 20 per cent greater than that required at full speed; this is not a serious matter.

3. **Small mechanical clearance.** In this particular motor the clearance is ⅛-in., which is ample for all practical purposes.

4. **Inequality of load on several motors of a locomotive due to differences in diameter of driving wheels.** To meet this an adjustable resistance is included in the rotor of each motor, the motors are then balanced up and no further attention is required as long as the wear on the driving wheels is approximately the same. If, at any time, the load becomes badly unbalanced it is a simple matter to readjust the resistances.

5. **Low power-factor of the system.** This does not seem to be borne out by practice. The power-factor, as shown by the switchboard instruments in the power house, is 85 per cent. This is a good result and is much higher than a power-factor of a well known single-phase system that I recently had occasion to visit.

6. **Two overhead wires.** There is no doubt that two wires will cause more trouble than one, and in case of complicated yard structure it might not be practicable to use two overhead wires; but where the problem is that of a single track with an occasional turn-out or crossing there is, practically speaking, no more difficulty in maintaining two wires than one.

In brief, in service, of this character the three-phase motor has marked advantages in capacity, reliability, simplicity, and general trustworthiness, when compared with any other motor.

Some Minor Advantages of Electric Traction.

In the many discussions of electric traction which have recently taken place, I do not find several minor advantages sufficiently emphasized. One of these advantages lies in the fact that with electric traction the exact performance and condition of the locomotives and of all elements of the system is accurately known at each moment; on the other hand, with steam locomotives neither the engineer nor the motive power man can have any clear knowledge of the conditions of operation at the moment; he can only ascertain the performance of the locomotive by elaborate tests, which, as a matter of fact, are seldom made. The ratings and performance of steam locomotives are made up largely by "authority" based on a few tests from time to time, and take no cognizance of the actual condition of the locomotives. The importance of this, I think, is clearly brought out by the tests of the steam locomotive cited herein.

With electric locomotives the operation on a heavy grade becomes as simple as on the level; the engineers and trainmen feel much greater confidence in the electric locomotives and consequently the mountain division ceases to be a terror to them.

Electric traction will permit the use of very long tunnels, which are not now possible on account of difficulty of ventilation. There is no particular reason why tunnels of ten or twelve miles should not be operated as easily as those of one mile.

The great increase possible in the speed of trains with electric traction and the consequent increase in the capacity of a single track will operate to postpone for a long time the necessity for double tracking. This double tracking on a mountain is a very expensive piece of business and this saving alone will, in some cases, more than offset the cost of electrical equipment.

Ventilating fans for motors are being installed on many electric locomotives and tests are being made as to their adaptability to all over-loaded electric railway equipment. The fans are either placed in the motor shaft or under the seats and supply air to cool the motor, thus increasing its overload capacity.

SOME PHASES OF TRANSFORMER REGULATION.[1]

BY W. A. HILLEBRAND AND S. B. CHARTERS, JR.

The following paper is based upon experiments conducted at Stanford University during the past two years upon the regulation of transformers under varying conditions. The first test was made upon a single phase, 200 watt, 11,000-110 volt meter-transformer, loaned for the purpose by the Pacific Gas and Electric Company. Owing to the importance of voltage and phase regulation in such a transformer, particularly when applied to the measurement of a large amount of power, a knowledge of its behavior in this regard is extremely desirable.

The remaining tests were made upon power transformers variously connected to polyphase networks, for the purpose of determining the cause and probable extent of the unbalancing in polyphase connections that occurs under certain conditions.

The connections investigated were:

Three-wire, two-phase system of distribution.

Open delta.

Scott two-phase to three-phase transformation.

Inasmuch as any transformer in a group feeding into a polyphase network behaves precisely as it would when operated from a single phase circuit under similar conditions of load and power factor, the performance of the group of transformers is to be explained on the basis of the performance of their individual units as single phase apparatus.

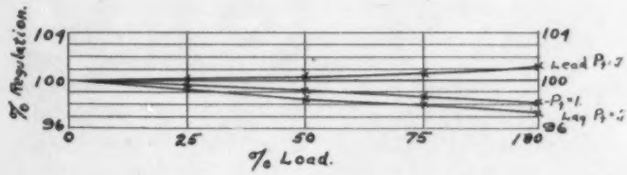


Fig. 1.

In Fig. 1 are shown regulation curves for a 4 k. w. single phase transformer operating at unity power factor and seventy per cent power factor leading and lagging.

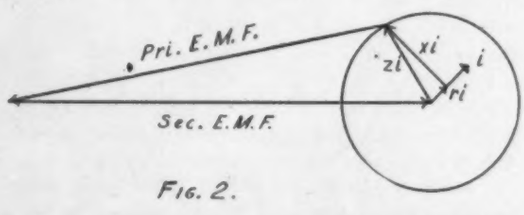


Fig. 2.

Fig. 2 shows the relation between primary and secondary e. m. f.'s in the single phase transformer with a 1:1 ratio, considered as a simple impedance connected across the circuit. The fact we wish principally to emphasize by means of this diagram is that the impedance of the transformer causes not only a variation in the amount of secondary voltages but also causes it to be displaced in phase.

With leading current the secondary e. m. f. is displaced more than if the power factor were unity and still more than if the current were lagging. This general relation is shown in Fig. 3.

[1]Read before San Francisco Section, A. I. E. E., October 29, 1909.

Meter Transformer.

Since, in most instaliations, special transformers are inserted between the power mains and the instruments, the accuracy with which the power is measured depends not only upon the inherent accuracy of the instruments but upon the regulation, both voltage and phase, of the transformers as well. Thus, if the secondary pressure of the meter transformer is lower than it should be, due to loading, the power recorded will be less than the real value. Also, if the phase angle between the currents in the pressure and field coils of the meter differs from that between line pressure and current, a second error is introduced.

It is well known that meter pressure transformers are provided by the manufacturer with additional secondary turns to compensate for the drop due to loading, so that when used at their specified load they give their rated voltage ratio and to give this ratio the load should be as nearly as possible that for which the transformer is compensated. It is comparatively easy in this way to compensate for voltage drop at any given power factor, but this will not compensate fully for the drop at a different phase relation between current and electro-motive force.

Theoretically it should be possible, by making the resistance very large in proportion to the reactance, to design a transformer of perhaps poor voltage regulation at unity power factor, but one which would give nearly the same drop over a range of power factors much less than unity.

Fig. 3.

An effort to accomplish this end might have been made in the transformer tested, in which the dimensions are as follows:

Ratio of turns—100; 1 approx.
Pri resis. = 5900 ohms.
Pri. resis. in sec. terms = 59 ohms.
Sec. resis. .306 "
Equivalent resis. = .896 "
Impedance, in pri. terms 9824 "
Impedance, in sec. terms .9824 "
Equivalent react. = .406 w
Voltages—11,000 to 110.
Capacity—200 watts.
Full load secondary current = 1.82 amp.

Fig. 4.

This shows an equivalent resistance of somewhat over twice the equivalent reactance, proportions entirely different from those in the ordinary power transformer, but in spite of this fact the voltage drop varies widely with the power factor, as shown by the curves in Fig. 4.

For full load current, between unity and 75 per cent power factors there is a difference of 1.6 per cent

in the voltage drop, the total drop being for the first case 2.7 per cent and for the second 4.3 per cent, quantities so large where the measurement of any considerable amount of power is concerned, as to necessitate, for accurate results, that the transformer be compensated at the factory not only for its specified load but also at the power factor at which that load operates. Otherwise the meters should be calibrated with the transformers to which they are connected.

A thorough investigation of the extent of the phase displacement of secondary voltage in pressure and current transformers has been undertaken by the National Bureau of Standards, the report on which may be found in abstract in the Electrical World for July 29, 1909. It will be published entire in one of the Bulletins issued by the Bureau. In the only report as yet printed no figures are given but the statement is made that "the shunt transformer is a device of high precision and that the same is true of the current transformer, but to a less degree."

It was the original purpose of this investigation to develop a method devised by Professor H. J. Ryan for the measurement of such phase displacement, and also of the effect of wave distortion, with the apparatus available in the ordinary laboratory or central station, but, after a large amount of experimental work had been performed instrumental errors were discovered which nullified the results. We hope, however, to give this method another trial.

Three-Wire, Two-Phase Connections.

Turning now, from the meter transformer to the subject of polyphase connections, we will take up the question of distributing two-phase power over three wires.

This connection was investigated because it is largely used in the distribution of power and the belief has been expressed that the throwing of quarter phased currents together into a common conductor will cause voltage unbalancing and phase distortion. This opinion is expressed in a recent and very popular laboratory text book, in which a diagram is given to show that such effects are produced. Like so many diagrams of this nature, however, in order to show anything at all the proportions are so greatly distorted that the figure fails to represent practical conditions.

In Fig. 5a is given a diagram, the proportions of which are likewise distorted, which, it is believed, takes account of all of the factors in the three distributing wires that affect the voltage as delivered to the receiver.

T_1 and T_2 are the quadrature source e. m. f's.

Φ_1 and Φ_2 are the receiver e. m. f.'s.

r_1, r_2 and r_3 are the resistances of lines *a*, *b* and *c* respectively and are all assumed to be equal.

x_1 is the reactance of line *a* with respect to circuit *ab*.

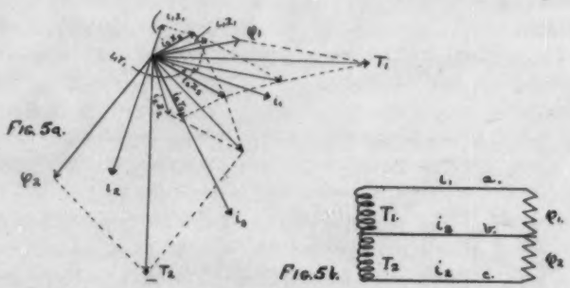
x_2 is the reactance of line *b*.

x_3 is the reactance of line *c* with respect to circuit *bc*.

i_1, i_2 and i_3 are the currents in *a*, *b* and *c* respectively.

There is also a transformer e. m. f. in circuit *ab*, induced by current in line *c*, and a similar e. m. f. in circuit *bc*, induced by current in *a*, but it is doubtful if these are ever of appreciable value, so that they have been omitted from an already crowded diagram.

The impedance drop in the middle wire, $i_2 z_2$. Fig. 5a does not combine symmetrically with T_1 and T_2 in producing the receiver e. m. f.'s Φ_1 and Φ_2. It is this fact which causes the increase in phase angle between the receiver pressures and the difference in their values.



In drawing conclusions from this diagram it must be borne in mind, first, that the resistance and reactance of the individual leads are magnified out of all proportion, and second, that the currents are assumed to remain equal and in quadrature. In an actual case, particularly if the load consists of induction motors, the last condition will not hold true because as soon as any unbalancing of voltage or phase occurs, unequal currents with different power factors are drawn, which check to a large extent the tendency to unbalance.

Two 4 k. w. 2200, 220 or 110 volt transformers were connected to a receiver through a line 95 ft. long, consisting of three wires spaced six and a half inches apart, the outers being No. 12 B. & S. and the middle of the same wire doubled for 41 per cent of the distance to give the same drop as either of the outers.

Resistance of each outer wire = .148 ohms.
Resistance of middle wire = .117 "
Reactance of each wire = .01 " (about)

The line gave, with full load on the transformers at 110 volts, about 12 per cent drop, and about 6 per cent drop with full load at 220 volts.

The results of a run on non-inductive load are given in table 1.

TABLE 1.

	VOLTS		AMPERES			
	Phase A	Phase B	Phase A	Phase B	Angle Phase Difference	Per Cent. Unbalance
No Load	110.4	110.5	0	0	90°48'	.09
Load	97.4	96.1	34.15	34.05	94°57'	1.34

These figures, showing an unbalance of 1.25 per cent and phase distortion of 4° 9', are of interest to the extent that they support the theoretical conclusion that there should be unbalance and phase distortion as a result of this connection.

When furnishing power to an induction motor at 220 volts the figures were, Table 2.

TABLE 2.

	VOLTS		AMPERES		Angle of Phase Difference.	Per Cent. Unbalance
	Phase A	Phase B	Phase A	Phase B		
No Load	220.8	220.1			89°46'	.3
Load	195.2	198.0	18.23	19.8	92°4'	1.414

Here there was an unbalancing of only 1.11 per cent and a shift in phase of 2° 18'.

In a diagram similar to Fig. 5a, which would attempt to show all of the electro-motive forces in their relative proportions for our particular line, the vectors representing the line losses would be of almost microscopic size, which leads to the conclusion borne out by our experimental results, that for any case likely to be met with in practice the unbalancing or phase distortion will not be serious.

The same reason that led us to investigate the subject of three-wire, two-phase distribution, also prompted the experiments on the open delta and Scott T, to determine to what extent these unsymmetrical connections may lead to unbalancing or phase distortion.

Open Delta.

Fig. 6 shows two transformers connected in V on a three-phase circuit with a three phase, delta connected, non-inductive load.

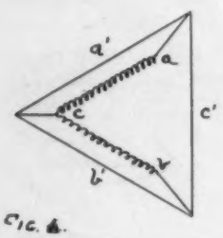


Fig. 6.

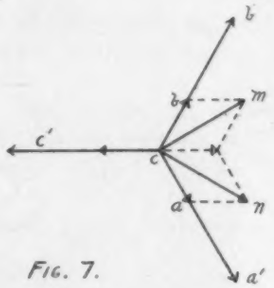


Fig. 7.

The currents in branches a^1, b^1, and c^1 are in phase with the electro-motive forces in their respective branches. Current in transformer *ca* is the vector sum of currents in a^1 and c^1. Similarly, current in *cb* is the vector sum of currents in c^1 and b^1.

In Fig. 7 are shown the vector relations of e.m.f.'s and currents in the load circuit.

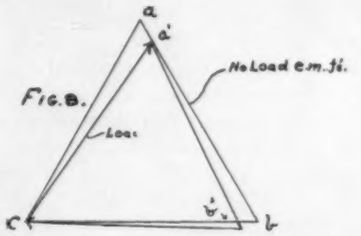
E. m. f.'s a^1 and b^1 are also the transformer e.m.f.'s *ca* and *cb*, respectively Fig. 6. The sum of currents in c^1 and a^1 is *cn* and the sum of currents in c^1 and b^1 is *cm*.

An inspection of this figure shows that in transformer *cb* the current is lagging by 30° and in transformer *ca* it is leading by the same amount. That is, each transformer, on non-inductive load, operates at 86.6 per cent power factor. The result of this can be readily seen by referring back to Figs. 1 and 3. The effect of leading current in transformer *ca* is to hold up the secondary voltage and shift it in phase behind its phase position on no load. In transformer *cb* the lagging current causes a greater drop in voltage, but shifts the phase less than in the other.

In Fig. 8 triangle *cab* represents the balanced e. m. f.'s of Fig. 6. Triangle ca^1b^1 shows the electro-motive forces on non-inductive load.

The effect of drawing load has been to destroy the equality of voltages and to change the angle between the two transformer e. m. f.'s.

It should be borne in mind that the angle between the transformer pressures *ac*, *bc* and a^1c b^1c, Fig. 8, is actually the exterior angle *c*, or 180° minus the angle here given. Thus, the actual effect of the delta connection is to slightly increase the angle between the two electromotive forces. For convenience in graphical representation the supplementary angle has here been treated.



In table 3 are shown the results of loading two 10 k. w. transformers in this manner.

TABLE 3.

	E. M. F.			Per Cent. Unbalance	Angle 'C' Fig. 8
	Phase 1	Phase 2	Phase 3		
No Load	254.4	253.2	253.4	.472	59°58'
Load	246.6	240.3	236.6	4.05	58°13'

Balanced non-inductive load, 50 amperes per phase. Phase 3 is the open phase.

With these particular transformers carrying approximately full load current, there was an unbalancing of 3.58 per cent and a change of 1° 45' in the phase angle between their pressures. A convincing demonstration of the fact that the current in one transformer is leading was obtained by inserting a choke coil in series, which caused an immediate increase in wattmeter reading, current and voltage remaining practically the same.

The regulation on non-inductive load is chiefly of theoretical interest.

The induction motor when operated from such a system exerts its customary regulating effect so that unbalancing and phase distortion are by no means so pronounced. Unfortunately, we had but one three-phase motor, which could load the transformers to only about half of their capacity so that regulating effects were not very marked. In table 4 are presented, however, comparative readings on non-inductive and induction motor loads of approximately equal value, which show relatively a greatly improved performance on inductive load over that on non-inductive load, although the unbalancing in either case was slight.

TABLE 4.

	E. M. F.			Per Cent. Unbalanced	Angle	
	Phase 1	Phase 2	Phase 3			
Non-inductive Load	232.1	230.3	231.7	0.776	60°12'	No Load
	229.2	224.4	223.9	2.31	59°11'	Load
Inductive Load	233.6	230.2	232.1	1.45	60°3'	No Load
	226.0	224.3	222.5	1.55	59°21'	Load

Phase 3 is the open phase. The currents were

27.9 and 27.2 amperes per phase for the non-inductive and the inductive loads respectively.

For the non-inductive load the unbalance and phase distortion were 1.53 per cent and 1° 0′. For inductive load they were 0.1 per cent and 0° 42′ respectively.

The above results are of value only as a check upon the theory that explains the regulation of V connected transformers. In the most unfavorable case, when full load current was drawn by a non-inductive receiving circuit, the unbalance was between three and four per cent. On inductive load the unbalancing would doubtless be considerably less, so that, judging from the performance of these two 10 k. w. transformers, which are representative of modern apparatus, the unbalancing resulting from the V connection or open delta is not likely to be serious, a conclusion doubtless in accord with practical experience.

When supplying induction motors with power factors of from 85 per cent to 90 per cent, one transformer operates at about unity power factor and the other operates at a power factor of from 50 per cent to 55 per cent, lagging.

With initially unbalanced primary circuits, the transformer with the high voltage draws a heavier current, which, however, if the power factor of that circuit is the high one, will on that account exert a correspondingly less regulating effect, whereas, the low power factor current in the other transformer will exert a relatively greater effect, so that there may be no improvement in line conditions with load, a particular case in which induction motors fail to balance up the line. This is brought out in table 5.

TABLE 5.

	E. M. F. 's			CURRENTS			Per Cent. Unbalance
	Phase 1	Phase 2	Phase 3	1	2	3	
No Load	230.1	216.8	223.8	0	0	0	5.8
Load	225.0	212.2	218.6	24.0	19.4	26.15	5.7

Referring to Fig. 6, phase 3 is the open phase *a-b*. Currents 1 and 2 are currents in transformers *a-c* and *b-c* respectively. Current 3 is the current in the lead wire from the junction point *C*.

Theoretically, then, the V connection of transformers will cause unbalancing, due to the different power factors at which the two operate, but with well designed apparatus supplying induction motors, this unbalancing should be small. With initially unbalanced circuits conditions may be such that the induction motors fail to exert any regulating effect.

These conclusions are based upon experiments in which the electromotive force was nearly sine wave in form. Where a pronounced third harmonic is present the pressure across the open side is much distorted, which might cause trouble aside from any phase distortion or unbalancing of the fundamental.

Scott T.

Fig. 9 gives the phase relation of currents and electro-motive forces in a system of two transformers T connected, supplying power to a balanced, non-inductive load. *ab* represents one transformer and *cd* the other.

From this diagram it is seen that currents of different phase relation flow in the two halves of the transformer which constitutes the top of the T. In one half, *ad*, the current is leading by 30° and in the other half lagging by the same amount. This means,

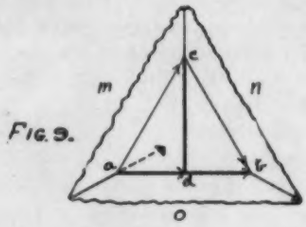


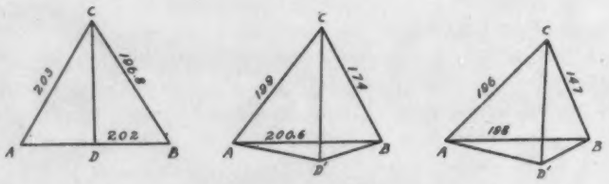
Fig. 9.

according to the curves in Fig. 1, that the regulation in the two halves will be different. Side *ac* of the delta e. m. f.'s will tend to hold up its voltage and side *bc* to drop off.

This is strikingly shown in Fig. 10, which represents to scale, no load, half load and full load voltage readings taken with the two 10 k. w. transformers used in the tests on the open delta. The lines ad^1 and d^1b show that the arithmetic sum of the voltages in the two halves of the transformer *ab* is no longer equal to the e. m. f. between its terminals. The unbalance from no load to full load was 22.7 per cent.

These transformers are of the core type, with a primary and a secondary coil on each leg, wound for 2200 or 1100 to 220 or 110 volts.

Fig 10.



In the run represented in Fig. 10 both primary and secondary coils were connected in series. That is, one-half of the secondary, represented by vector *ad* Fig. 9, occupied one leg, and the second half *db* occupied the other leg. This is shown in Fig. 11.

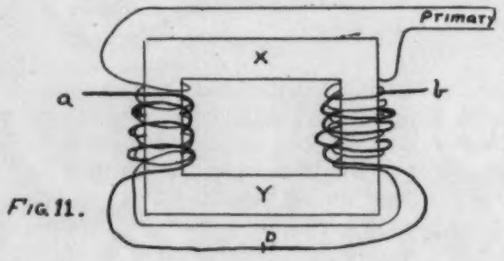


Fig. 11.

The significance of this fact is as follows: In ordinary single phase operation the ampere turns between points *x* and *y* on the core are zero. That is, there is no magneto-motive force tending to establish leakage flux via the route *xy*. When, however, leading current flows in leg *ad* and lagging current in leg *bd* this is no longer true.

In single phase operation the draught of load current draws current from the primary whose ampere turns neutralize the secondary load ampere turns. In

this case, however, with primary coils in series, but one load current can flow, which can only neutralize the vector sum of the two secondary currents. This relation is shown in Fig. 12, which represents the primary and secondary currents reduced to a 1:1 ratio.

At the instant represented by point *o*, Fig. 12, the primary ampere turns are zero, but in the two secondary coils the ampere turns are equal and opposite. This condition is represented in Fig. 13. At this instant the ampere turns between *x* and *y* are fifty per cent of the maximum ampere turns of either secondary coil. The result is an enormous leakage flux with consequent atrocious regulation. So great was the leakage flux with our particular transformer that the case became hot, due to eddy currents set up by the stray field.

With primaries in series as before, but secondaries in parallel, furnishing 110 volts instead of 220, the regulation is greatly improved, as shown in Fig. 14,

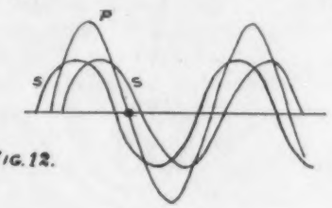


FIG. 12.

which represents no load, half load and full load voltage readings with the secondaries of both transformers in multiple.

The unbalancing from no load to full load is 2.3 per cent as against 22.7 per cent for the series connection.

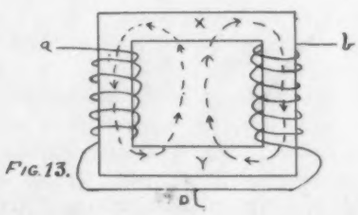


FIG. 13.

When secondaries are connected in parallel the condition represented in Fig. 12 holds true for each leg of the transformer, but as the secondary winding on each core is split into two concentric coils, one completely covering the other, the ampere turns of the two halves at the instant o neutralize each other not only with regard to a path through the core but with regard to the path *xy* as well, as shown in Fig. 15. For the sake of clearness the two halves of each secondary coil are shown separately.

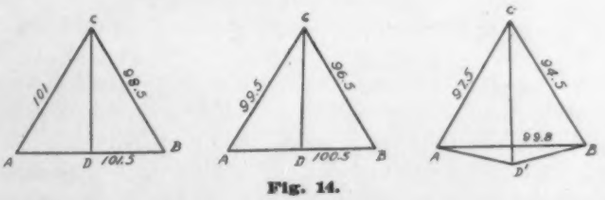


Fig. 14.

The result is a greatly reduced leakage flux with consequent improvement in regulation.

By cross-connecting the secondaries, that is, by connecting terminals 1-3 and 2-4 together respectively, the condition shown in Fig. 15 could be realized for the series connection, with secondary voltage of 220,

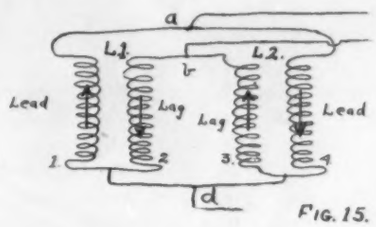


FIG. 15.

and good regulation would result, but the regulation with secondaries in parallel would then be poor.

As a further experiment, the two halves of the primary winding of transformer *ab*, Fig. 9, were each excited by means of separate transformers at 1100 volts, equivalent to placing the two primary coils in parallel across an eleven hundred volt circuit. With secondaries connected in series, the secondary current in one leg is leading and in the other lagging, but with each primary coil supplied independently of the other, it could draw load current whose ampere turns would at all times equal those of its corresponding secondary, as in the single phase transformer. The result was small leakage flux and good regulation.

TABLE 6.

	E. M. F.'s				
	Phase 1	Phase 2	Phase 3	Per Cent. Unbalance	Average Amperes per Phase
No Load	221.8	220	220	0.82	
Load	200	194.6	192.0	4.0	38.9

With this connection the unbalance from no load to full load was only 3.2 per cent as against 22.7 per cent for both primaries and secondaries in series. The currents were 41.9 and 47.1 amperes per phase for the parallel and series connection of primaries respectively.

As a final experiment, three transformers were used, *ab* and *db*, Fig. 9, each consisting of half of an independent transformer. This does away with complications due to leading and lagging currents in the same transformer and gives good regulation whether primaries are connected in series or in parallel.

Using three transformers, the unbalancing from no load to full load, secondaries in series, was .85 per cent. With secondaries in parallel the unbalancing was .63 per cent. These were for non-inductive loads. When operating induction motors, the unbalancing was less, or even an improvement over no load conditions, for, not having a tap on the transformer used as the stem of the T that was approximately 86.6 per cent of the base, the secondary voltages were initially unbalanced between one and two per cent.

Our tests were all based on transformation from two to three phases. When transforming from three to two-phase it is the primary of one transformer that carries different power factor currents in its two coils, but the effect would be the same as with similar currents of equal ampere turns in the secondary coils, so that any conclusions drawn from these experiments should apply equally well to both cases.

Wherever serious unbalancing is caused by T connected transformers, transforming from two to three-phase, or the reverse, it is probably due to excessive leakage flux caused by different power factor currents that circulate in the two halves of the transformer comprising the top of the T. This leakage flux may be greatly reduced and regulation correspondingly improved:

1. By proper interlacing of the transformer windings; secondaries if transformation is from two to three phase; primaries if the reverse.

2. By joining in multiple the two halves of the transformer used as the top of the T, on the side that connects to one of the two-phase circuits.

3. By using three transformers, where available.

In conclusion, we wish to acknowledge our obligation to Professor Harris J. Ryan for the assistance which we received from him on numerous occasions during the conduct of these experiments.

ALCOHOL ENGINES.

The United States Geological Survey, has just issued a bulletin on "Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines," by Robert M. Strong. The tests, which were under the technical direction of R. H. Fernald, engineer in charge of the producer-gas section of the Technologic branch, were conducted at the fuel testing plant in St. Louis, Mo., and at Norfolk, Va. The tests dealt primarily with gasoline, forming part of the investigation of mineral fuels provided for by acts of Congress. To determine the relative economy and efficiency of gasoline it was compared with denatured alcohol. When the series of tests was started, it was found that it took from one and one-half to two times as much alcohol as gasoline to produce a given power. With special alcohol engines, entirely suited to the use of alcohol, the latter fuel has been made to do as much work, gallon for gallon as the gasoline.

On this point, the bulletin states: "By using alcohol in an alcohol engine with a high degree of compression (about 180 pounds per square inch above atmospheric pressure—much higher than can be used for gasoline on account of pre-ignition from the high temperatures produced by compression) the fuel consumption rate in gallons per horsepower per hour can be reduced to practically the same as the rate of consumption of gasoline for a gasoline engine of the same size and speed. The indications are that this possible 1 to 1 fuel consumption, ratio by volume, for gasoline and alcohol engines, will hold true for any size or speed, if the cylinder dimensions and revolutions per minute of the two engines are the same."

A gasoline engine having a compression pressure of 70 pounds but otherwise as well suited to the economical use of denatured alcohol as gasoline, will, when using alcohol, have an available horsepower about ten per cent greater than when using gasoline.

In regard to general cleanliness, such as absence of smoke and disagreeable odors, alcohol has many advantages over gasoline or kerosene as a fuel. The exhaust from an alcohol engine is never clouded with a black or grayish smoke, as is the exhaust of a gasoline or kerosene engine when the combustion of the fuel is incomplete, and, it is seldom, if ever, clouded with a bluish smoke when a cylinder oil of too low a fire test is used or an excessive amount supplied, as is so often the case with a gasoline engine. The odors of denatured alcohol and the exhaust gases from an alcohol engine are also not likely to be as obnoxious as the odor of gasoline and its products of combustion.

Very few alcohol engines are being used in the United States at the present time, and but little has been done toward making them as adaptable as gasoline engines to the requirements of the various classes of service. Engines for stationary, marine, and traction service, automobiles, motor trucks, and motor railway cars designed especially to use denatured alcohol, have, however, been tried with considerable success.

The price of denatured alcohol is greater than the price of gasoline, and the quantity of denatured alcohol consumed by an alcohol engine as ordinarily constructed and operated is in general relatively greater than the quantity of gasoline consumed by a gasoline engine of the same type. Considerable attention is being given to the development of processes for the manufacture of alcohol from cheap raw materials which are generally available, and it seems reasonable to expect that the price of denatured alcohol will eventually become as low or lower than the price of gasoline, especially if the price of gasoline advances. It also seems reasonable to expect a greater general improvement in alcohol engines than in gasoline engines.

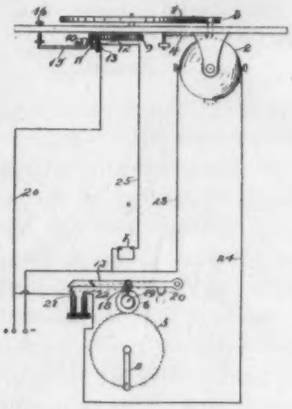
When used as a fuel, denatured alcohol is not always so classed as to be exempt from restrictions placed on the use of gasoline by the rules of insurance and transportation companies or city ordinances. The restrictions that are placed on the use of denatured alcohol are, however, never greater than those placed on the use of gasoline. In some places, they are such that the use of an alcohol engine is permitted where the use of a gasoline engine is prohibited. For instance, alcohol motor trucks, and automobiles are admitted to many of the steamer piers in New York that are not open to gasoline machines.

When the restrictions placed upon the use of denatured alcohol are less than those placed on the use of gasoline or where safety and cleanliness are important requisites, the advantages to be gained by the use of alcohol engines in place of gasoline engines may be such as to overbalance a considerable increase in fuel expense, especially if the cost of a fuel is but a small portion of the total expense involved, as is often the case. Denatured alcohol, will, however, probably not be used for power purposes to any great extent until its price and the price of gasoline becomes equal and the equality of gasoline and alcohol engines in respect to ability to service required and quantity of fuel consumed per brake horsepower, which has been demonstrated to be possible, becomes more generally realized.

A further general development in the design and construction of engines that use kerosene, or cheaper distillates, and the crude petroleums may be reasonably expected and may delay the extensive use of denatured alcohol for some time to come, but as yet comparatively few data pertaining to this phase of the general investigation are available.

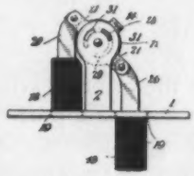
PATENTS

939,337. Synchronizing Device for Picture Machines and Phonographs. Paul Seiler, Oakland, Cal. In a combination picture machine and phonograph apparatus, a picture machine, a phonograph, a motor circuit, a ticker circuit, a rythmical make and break device in said ticker circuit, means



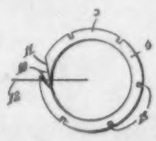
for independently setting said picture machine, rythmical make and break device, and phonograph at their respective starting points, and means for closing said circuits simultaneously.

939,599. Two-Pole Snap-Switch. Louis Kellner, New York, N. Y. In a switch of the class described, a standard having a stud, a sleeve longitudinally and angularly movable on said stud, switch elements angularly movable with said sleeve, a rocker plate and spring for tensioning the said



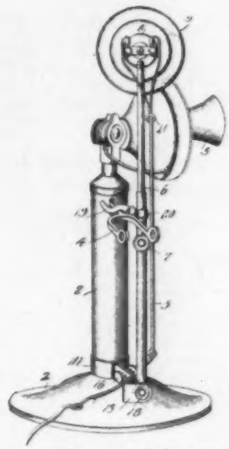
switch elements and sleeve to move angularly, push buttons connecetd to said rocker plate to oscillate the same, means forming part of said standard for initially restraining movement of said sleeve, and means forming part of said rocker plate for releasing said restraining means.

939,501. Coupling for Electric Conductors. Jesse L. Hinds, Syracuse, N. Y., assignor to Crouse-Hinds Company, Syracuse, N. Y. A coupling for electric conductors comprising a compressible sleeve and means for compressing the same, the sleeve having a smooth bore for receiving a conductor and making electrical contact therewith throughout substantially



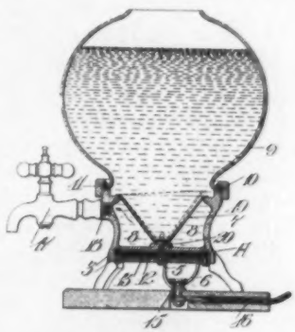
the extent of said bore, said sleeve having a length-wise slot extending transversely therethrough, the opposing walls of the slot inclining in the same general direction, and one of such walls being disposed substantially tangential to the bore of the sleeve adjacent to the opposite wall of the slot, whereby the slot is provided at one side thereof at the meeting surfaces of said tangential wall of the slot and the bore of the sleeve with a relatively thin and flexible lengthwise edge which coacts with the opposing inner edge of the slot and enters the bore of the sleeve in a direction substantially tangential to such bore without materially altering the curvature of the sleeve or injuring the conductor within said sleeve, thus adapting the sleeve for use on electric conductors of different diameter, substantially as described.

939.439. Telephone Attachment. Henry R. Palmer, Seattle, Wash. In a desk set, the combination with the transmitter supporting column, of a clip consisting of a metal strap encircling said column, and having the opposite ends thereof brought into parallel relation to each other to form clamping jaws disposed at an angle to the line of projection of the mouth piece of the transmitter, a clamping screw connecting said jaws, a tubular receiver supporting standard



embodying telescopic sections and having its lower end held between the clamping jaws of said clip adapting said standard to swing toward and away from the receiver hook at an angle to the line of projection of the mouth piece of the transmitter, and a disconnecting arm adjustably mounted on said standard and adapted to interlock with the receiver hook of the transmitter and hold the receiver standard in an upright position.

939,605. Electric Water-Heater. Henri G. Levy and George N. Blanchard, San Francisco, Cal. A heating unit comprising two sheets of insulated material the opposed surfaces of which are normally coated with a binder which will



become active on the application of heat thereto. and a winding of bare metal and insulating material between the sheets forming a flat insulated coil, said winding being united to the sheets to bind the several parts and thereby form a substantially rigid heating element.

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By cancelling an unissued block of nine million dollars worth of municipal bonds, unsold because of their low rate of interest, the San Francisco Board of Supervisors has paved the way for the authorization of an issue of nearly fifty millions for the Hetch Hetchy and Geary-Street Railroad projects. Late in December the voters are to decide whether they wish to pay $45,000,000 for a municipal water supply from the Sierra Nevada Mountains and whether they will involve the city in the difficulties of constructing and operating an electric railroad.

One of the most absurd rulings yet proposed by the adherents of corporation regulation is that by which the United Railroads of San Francisco should issue a fare slip, good for five days, whenever a car is halted for a period of five minutes by the failure of power or other causes. The proposition is absurd in that it involves the small sum of five cents for each passenger, and unjust in that the causes of car stoppage are usually beyond the control of the railway company. There is no one more vitally interested in continuity of service than is the operating company. There is no great likelihood that the measure will be passed, as there is a further question as to its constitutionality.

The illustrated description of the Great Northern three-phase electrification which appeared in these columns on July 24, 1909, should be regarded as supplementary to the more detailed paper by Dr. Hutchinson which we abstract in this issue. His concluding summary of the advantages and disadvantages of this novel system promise for it a more extended application than it has yet received. With a continuance of its initial success the electrification will be extended to embrace the entire mountain division from Leavenworth to Skykomish, a distance of 67 miles. Incidentally, the paper calls attention to the manifold advantages of electric traction under what are ordinarily the most trying conditions of railroad operation.

The absorption of the Western Union Telegraph Company by the American Telephone and Telegraph Company, aside from the interest that centers in a billion dollar corporation, exemplifies the economical results of consolidation. The great network of wires with which this country has been covered by the telegraph company becomes immediately available for telephonic communication, forming a valuable auxiliary to the greater network of existing telephone lines. The saving in new construction alone is estimated at seventy-five million dollars. The speculation that is rife as to the immediate possibility of all communication by wire being vested in one concern is idle. The independent companies are to-day too strongly intrenched to allow such monopoly. Furthermore, the many improvements being made in wireless communication of intelligence bid fair to make it a formidable factor in the future.

Transformer Regulation

In connection with the excellent paper on "Some Phases of Transformer Regulation," appearing elsewhere in this issue, it may not be amiss to summarize and explain some of the facts that Mr. W. A. Hillebrand and S. B. Charters, Jr., of Stanford University have presented in mathematical shorthand.

The constant potential transformers that they experimentally tested were used to step down a high supply voltage to a lower delivered voltage. Such a transformer consists essentially of two coils of insulated wire wound on an iron core. The current flowing in the "primary" winding, which is connected to the supply wires, magnetizes the iron core, which in turn induces an electro-motive force in the "secondary" winding, so connected as to deliver current to the load. The delivered voltage bears the same ratio to the supply voltage as does the number of turns in the primary to the number of turns in the secondary winding. This proportion is approximate because in practical operation there are certain losses due to resistance, reactance and leakage flux within the transformer. The efficiency of the transformer is determined by the watts lost and its regulation, with which we are here concerned, depends upon the volts lost.

This regulation is technically defined in terms of a mathematical ratio which involves the change of the delivered voltage with change of load, the supply voltage being assumed constant. In addition to this regulation as regards change of load, there are differences in the design of transformers that greatly influence their inherent regulation. Prominent among these is the correct proportioning of resistance and reactance and the minimizing of leakage. By adding several turns to the secondary coil, it is possible to compensate for the voltage drop due to loading, but this does not compensate for the drop at a different phase relation between current and electro-motive force.

With poor regulation the voltage drop with increase of load is familiarly seen in the annoying fluctuation of an incandescent light as more or less lamps are thrown on the circuit. The drop due to distortion of phase has been sometimes noted when an unsymmetrically connected transformer inexplicably burns out; inexplicable to the station attendant, but plain to any one taking the trouble to carefully read the accompanying paper and its following discussions. It is further exemplified by the fact that it is not advisable to use transformers designed for 60 cycles on 25 cycle circuits. For, in addition to the danger of their burning out, there is an error in the power measured by wattmeters.

As pointed out by the authors, this unbalancing of voltage and phase, due to certain combinations of transformers, may be corrected by others. Its effects have heretofore been little understood, but they are serious enough to warrant careful supervision of all transformer connections whose unbalancing produces unequal currents and may even go so far as to limit the capacity of motors.

The Engineer In Politics

If watts could vote, if the slide rule controlled the caucus, or if draftsmen drew up political platforms, the President of this country might be an engineer. As it is, the engineer is so busy with materials that he neglects men. He controls the power of water, steam or gas, but he does not guide human affairs. His judgment is sought on the strength of materials, but is sometimes faulty on the strength of human character. Leadership is a specialized business in which the ordinary engineer has not perfected himself, and is consequently ignored in the selection of a public service commission which is supposedly made up of "broad-minded men of affairs, who know the community and are beyond the suspicion of corporation influence." This criterion is one reached by many engineers whom we all can name, but unfortunately their qualifications are not known to the political powers. The engineer has not taken the trouble to cultivate the acquaintance of the politician.

He is perhaps no more blameworthy in this respect than the great majority of men, some of whom do not take the trouble to vote. If some men did not make a business of politics, if they did not organize and mold public opinion, it would be but a few years before self-interest would divorce many of us from an interest in community affairs. The political machine is making plans for the next campaign while the reformers are rejoicing over their temporary victory. The regular army usually gets away with the militia.

It therefore behooves the engineer to think and talk of something besides "shop." His training and his experience have eminently fitted him to direct those matters which now concern our government. Many municipalities are issuing bonds for public improvements, sewers, water-works and roads. They are interested in regulation and control of public service corporations. These are functions for whose discharge the engineer is peculiarly qualified.

He will naturally say that his duties are so all-absorbing as to preclude the possibility of his taking an active interest in things political. Civic service is a duty that we owe to the country to which many of us are indebted for our education. In European countries this debt is compulsorily paid in military service. In this land of liberty the service which an engineer can render should at once constitute his duty and his happiness. From the ground of public duty, the engineer should take a more active and practical part in the administration and direction of public affairs. We have no continuous partnership with the Almighty, though some of us seem to think that we have a personal guarantee that He will guide and guard our popular destiny. The market price of liberty has ever been the same—eternal vigilance; and if we think our political institutions are worth continuing, it is up to just such men as the engineers to lend efficient service in securing such perpetuity.

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Neither shall it be used for political or religious purposes. Its meetings shall be devoted to the business of the Association, and at all times preference shall be given to the education of engineers, and to securing the enactment of engineers' license laws in order to prevent the destruction of life and property in the generation and transmission of steam as a motive power.

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No. 5. Santa Barbara. Geo. W. Stevens, 2417 Fletcher Ave., R. R. No. 2.

No. 6. San Jose. Wednesday. Pres., W. A. Wilson, Sec., Lea Davis, 350 N. 9th St.

No. 7. Fresno. Pres., A. G. Rose. Sec., E. F. Fitzgerald, Box 651.

No. 8. Stockton. Thursday, Masonic Hall. Sec., S. Bunch, 626 E. Channel St. Pres., H. Eberhard.

Oregon.

No. 1. Portland. Wednesday, J. D. Asher, Portland Hotel. Pres., B. W. Slocum.

No. 2. Salem. A. L. Brown, Box 166.

Washington.

No. 2. Tacoma. Friday, 913½ Tacoma Ave. Pres., Geo. E. Bowman. Sec., Thos. L. Keeley, 3727 Ferdinand St., N., Whitworth Sta.

No. 4. Spokane. Tuesday. Pres., Frank Teed. Sec., J. Thos. Greeley, 0601½ Cincinnati St.

No. 6. Seattle. Saturday, 1420 2d Ave. Pres., H. R. Leigh. Sec., J. C. Miller, 1600 Yesler Way.

Practical letters from engineers and news items of general interest are always welcome. Write your items regardless of style. Communications should be addressed to the Steam Engineering Editor.

SAN FRANCISCO NO. 1.

A. G. Jones of the General Electric Company delivered a lecture on controlling devices, arc lamps and the mercury rectifier, on Thursday evening, November 18th. No. 1 has secured a fine hall at 172 Golden Gate avenue, which will be occupied on and after December 2d, every Thursday evening, and in which will be given a "house-warming" in the near future. President P. L. Ennor has offered a suitable token to the member who secures the greatest number of applications for membership between now and the first week in July, 1910. The token will be selected by a committee of three and will be donated by President Ennor personally. According to the manner in which the blank applications were sought at last meeting, it seems that a lively contest has been inaugurated.

CALIFORNIA NO. 3.

California No. 3 held an open meeting on Wednesday evening, November 3d, in the engine room of the Merchants' Exchange Building, where a lecture and practical demonstration of the analysis of flue gas was given by Mr. R. F. Chevalier. Mr. Chevalier was equipped with the Orsat apparatus, draft gauge, pyrometer, etc., and gave a complete demonstration of the process of analyzing the waste gases from the furnace. After explaining the operation of the instrument and giving a description of the evolution from the oil to the gas, a number of samples of the products of combustion were drawn from the uptake, each one under different conditions. They were then analyzed, and the results put upon the blackboard showing the amount of CO_2 and excess air, each result varying as the intensity of the fire was increased or decreased. The lecture was closely followed by some fifty members and friends of California No. 3, who thoroughly appreciated the opportunity of seeing this most important phase of engineering, the knowledge of which is so essential to the economical operation of a plant.

The lecturer was accorded a rising vote of thanks by his auditors, and it was conceded by all that it was one of the most beneficial of the many given in the past under the auspices of the educational committee. Mr. Chevalier again took up this subject for discussion at the meeting on November 10th, answering many questions relating to the subject which the members desired to have explained.

The educational committee is contemplating the purchase of the Orsat or some similar instrument for the use of the members who may be desirous of analyzing the waste gases of their plants. A number of equally interesting subjects are to be lectured upon during the coming winter.

PERSONALS.

P. H. Coolidge, assistant general manager of the Pacific Telephone & Telegraph Company, is in the Northwest.

Thos. Collins of the San Francisco office of the Westinghouse Electric & Manufacturing Company is in Los Angeles.

A. C. Smith, who has been chief inspector of the Ogden, Utah, Rapid Transit Company, has been appointed assistant superintendent of the company.

Robert Marshall, purchasing agent of the Standard Electrical Works, San Francisco, is the happy father of a baby girl. The present arrived November 14th, 1909.

J. B. Ingersoll has resigned as electrical engineer of the Spokane & Inland Empire Railroad, Spokane, Wash., to engage in other engineering work.

C. E. Allen has joined the Westinghouse Electric & Manufacturing Company in connection with the sales of transformers. Mr. Allen was formerly connected with the General Electric Company in a similar capacity, but resigned from that company during the past summer.

TRADE NOTES.

E. C. Fox and G. F. Pettit have started an electric wiring and supply business with offices in the Cors & Wegener building, Ballard, Seattle, Wash.

The Western Gas Engine Company of Los Angeles have completed the installation of a 500 h. p. plant for light and power purposes at Maricopa, California, consisting of gas driven generator and Nix Frost producer gas machine.

The Smith, Booth, Usher Company of Los Angeles, recently installed for the Union Tel. Company at Stevens Station, California, a Gould vertical triplex power pump, 6½x12, and a Gould horizontal triplex power pump, 4½x18, both driven by 175 h. p. Nash vertical gas engine, operated by waste gas from oil wells. The plant also includes a 12 h. p. St. Marys distillate engine and generator for lighting purposes. At Harris Station the same company installed a Gould vertical triplex power pump, 6½x16, driven by 125 h. p. Nash gas engine. These are the first power pumps installed for this purpose. Using the waste gas from the wells, they effect a great saving in fuel expense.

The Pelton Water Wheel Company have under course of construction in their San Francisco shops a special cylindrical encased Pelton-Francis turbine to operate under 47 ft. head and to revolve at a speed of 200 r. p. m. The turbine will carry on its shaft a large wire rope sheave, together with a re-winder sheave. The plant is intended for transmitting some 250 mechanical h. p. by means of a single wire cable over an incline to permit delivering the power of the line shaft to a coffee factory some 350 ft. distant. The idler sheaves will be carried in a special structural steel tower having a height of some 60 ft. Considerable importance is attached to this particular contract, as it is intended for foreign shipment and drives the machinery of a large coffee estate. The entire equipment is to be erected before shipment.

INDUSTRIAL

TYPE RI SINGLE PHASE MOTOR.

It has now become common practice for both central stations and isolated plants employing polyphase generating units to feed large portions of the lighting circuits as well as that part of the power load required for machinery of moderate capacity, through single-phase distribution lines.

Fully recognizing the permanent field for single-phase motors, the General Electric Company has paralleled its well-known poly-phase design with two lines of single-phase motors. The KS type is well known and thousands are now in successful operation. The RI motors of the repulsion induction type will be described in this article.

In general the type RI motor is distinctly adapted to the operation, by belt, gears or rigid couplings, of all machines requiring constant or variable speed and moderate or heavy starting torque. They are entirely automatic, and may be thrown on the line without the interposition of any starting box, clutch coupling, or other external device.

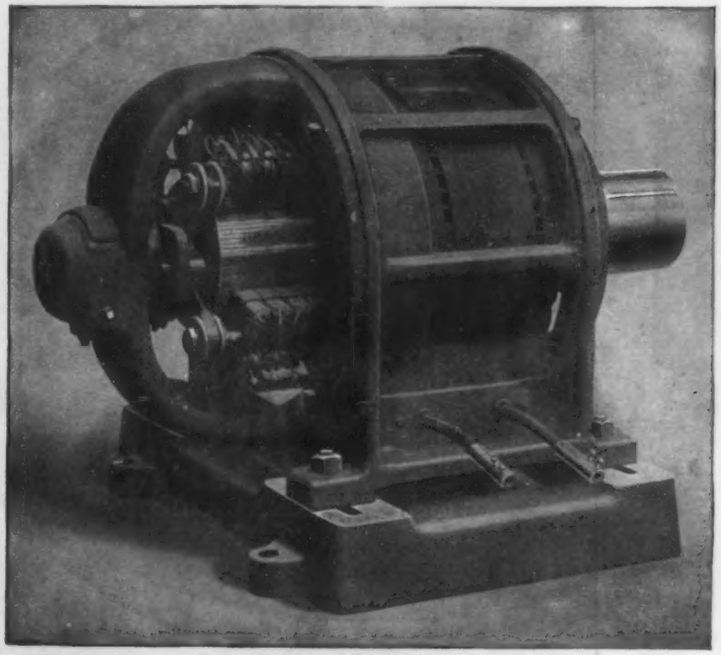


Fig. 1. Type RI Repulsion Induction Motor.

RI motors are built in the unique and well-known open frame form, which consists in clamping the laminations of the stator core between cast-iron flanges held in the frame to which the end heads are secured. This construction provides a most simple and effective method of natural heat radiation, since the laminated stator discs are exposed directly to the air. In addition, all inactive material is thus eliminated, weight is reduced, and without sacrificing rigidity, efficiency or quality in any respect, the motor is made exceedingly compact and more readily accessible for cleaning than with the older form of box frame design. Also pockets for the accumulation of dust are avoided.

The field of the RI motor is wound with a single-phase winding of the concentric type, each coil being taped and insulated separately. When completed, the stator coils receive a japan and baking treatment to render the insulation impervious to ordinary dampness or moisture.

To facilitate connection to circuits of either 110 or 220 volts, four plainly tagged leads are brought out to the back of the removable terminal board.

The RI armature winding is of the series drum type connected to a commutator carrying two sets of brushes, each set being displaced electrically from the other by 90 degrees. The first set, known as the energy brushes, is permanently short-circuited and disposed at an angle to the lines of field or primary magnetization, as in an ordinary repulsion motor. The second set, or compensating brushes, is connected to a small portion of the primary winding included in the field circuit, so as to impress upon the armature an electro-motive force which serves both to raise the power factor and at the same time maintain approximately synchronous speed at all loads.

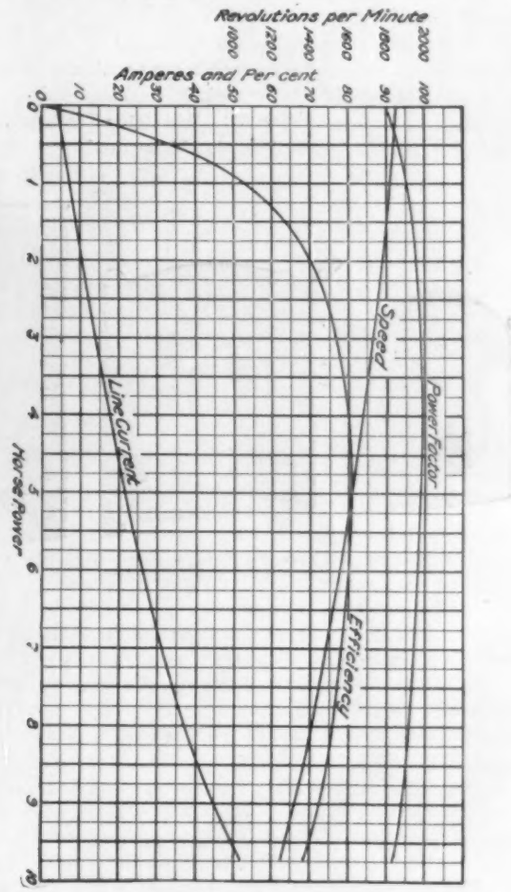


Fig. 2. Characteristic Curve of 5 h. p. Type RI Motor.

The armature laminations are built up on a cast-iron sleeve having the same inside bore as the commutator. In case the shaft becomes damaged or worn, it can be readily pressed out and replaced without disturbing the commutator or windings.

The bearings are of the oil ring type and of ample size to minimize wear and ensure cool operation. Solid rings are used, which revolve loosely on the shaft and dip into reservoirs of proper capacity to provide constant lubrication of the journals and linings. The reservoirs are fitted with visible gauges to indicate the amount of oil, and with taps for drawing off the lubricant when required. As will be noted, the double arm construction of the bearing heads permits ready access to all parts of the commutator and brush gear.

The standard method of interchangeably spacing the end

head retaining bolts is used, allowing the motor frame to be shifted 90 or 180 degrees for wall or ceiling suspension as desired The standard sliding base frame furnished with each machine is slotted and provided with float bolts to properly secure and allow adjustment of its motor feet for either floor, wall or ceiling operation.

Standard RI motors are wound for 60 cycles and are interchangeable for 110 or 120 volts, capacities ½, 1, 2, 3 and 5 h. p. The full load speed is as follows: ½ h. p., 1625 r. p. m.; 1 h. p., 1720 r. p, m.; 2 h. p., 1725 r. p. m.; 5 h. p., 1625 r. p. m.

A study of the curve, Fig. 2, covering the performance of a standard 5 h. p. RI motor will show at once the remarkably high and well sustained power factor and efficiency characteristics of the RI motors.

RI motors can be furnished with controllers to give a speed variation of 50 per cent below synchronous speed by inserting resistance or reactance in the energy and compensating circuits. With the exception of the leads brought out from these circuits the constant speed and variable speed motors are identical.

Reversible motors can be furnished at the slight additional cost of a special winding having terminals for connection to a four-pole double-throw switch.

For controlling Type RI Repulsion Induction Motors CR-118 or CR-172 controllers should be used.

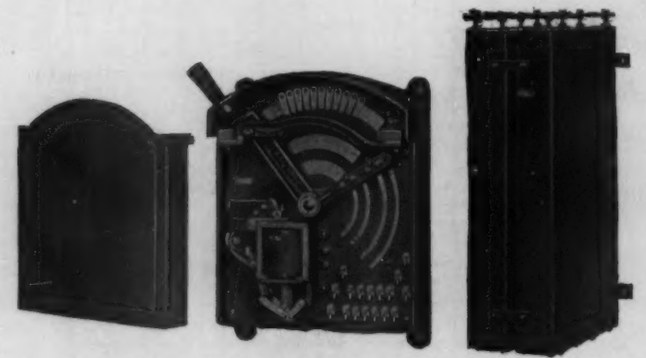


Fig. 3. Type CR-172 Controller and Resistance for 3 and 5 h. p. RI Motors.

The CR-118 rhetostats are designed for starting duty only and are recommended for operation on circuits where it would be objectionable to throw the motor directly on the line. A no-voltage release coil allows the rheostat starting arm to automatically return to the "off" position in case of line voltage interruption.

The CR-172 controllers are designed to give speed reduction and speed increase, as resistance is inserted in the energy and compensating circuits. The standard controller gives approximately 2:1 speed variation.

The controllers for 3 and 5 h. p. 110 and 220 volt motors are shown in Fig. 3. The resistance for the compensating circuit is self-contained, while the resistance for the energy circuit is external, being assembled in a well-ventilated sheet iron box suitable for mounting on the wall. These controllers have an enclosing cover, renewable segments, and in addition are supplied with an a. c. contactor. The contactor acts as a no-voltage release and also makes and breaks the motor circuit, thus preventing arcing on the switch contacts.

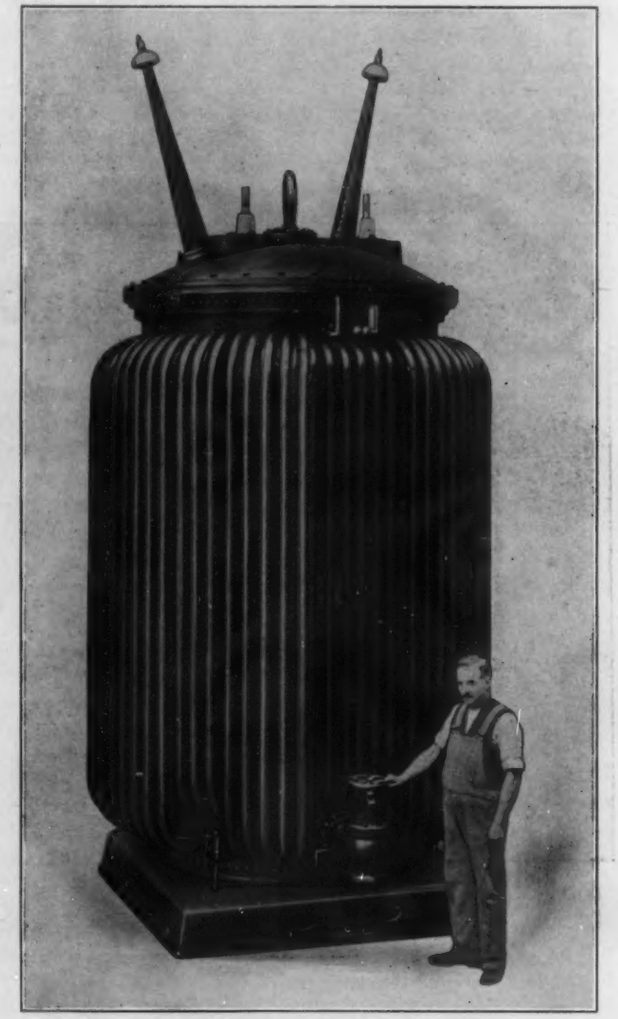
At present the RI motors are built in 5 sizes—½, 1, 2, 3 and 5 h. p.

The advantage of this type of motor may be briefly stated as: Noiseless operation, attractive design, improved ventilation, excellent heating and overload characteristics, compact and rigid construction, least weight consistent with proper mechanical strength and the sustaining of high electrical constants, self-starting with rapid acceleration, and wide speed control.

LARGEST SELF-COOLING TRANSFORMERS EVER BUILT.

The maximum size for which a transformer can be built self-cooling is limited by the amount of heat-radiating capacity for which the case can be designed. Standard cases with corrugated sides are regularly supplied with transformers up to about 600 or 750 kva., but beyond this size the weight and size of case became so great that some method, other than mere increase in size, must be resorted to in order to get the necessary radiating surface.

A type of case recently developed by the Westinghouse Electric & Manufacturing Company overcomes this difficulty and is capable of being designed for a greater radiating capacity than has ever been attempted for a self-cooled transformer. It consists simply of a plain boiler-iron case to the outside of which are welded a number of radiating tubes.



1000 kva, 100,000 Volt Self-Cooling Transformer.

These tubes are in the vertical position and are given a 90 degree bend at the top and bottom where they enter the case. The mechanical construction is very strong so that there is practically no chance of ever springing a leak. Because of the ease with which the tubes can be widely separated from one another, the air circulates very freely among them and the efficiency of the radiating surface is constantly higher than for the ordinary corrugated case.

The Westinghouse Electric & Manufacturing Company has just built twelve 1000-kva., 100,000-volt transformers of this type, shown in the illustration, for the Southern Power Company; three of these transformers are for outdoor service and nine for indoor.

NEWS NOTES

FINANCIAL.

SANTA BARBARA, CAL.—A resolution has been passed calling for the passage of an ordinance for the sale of a large amount of water bonds.

SEATTLE, WASH.—Stockholders of the Pacific Coast Power Company will hold a meeting December 20 to increase the capital stock from $7,000,000 to $15,000,000.

INCORPORATIONS.

DALLAS, ORE.—Dallas Telephone Company of Dallas, $25,000, by C. B. Sunderberg, Henry Berning and J. J. Keber.

MARCUS, WASH.—The Marcus Water Company of Marcus, $2000, by W. W. Tilghman, W. C. Goss, W. T. Kirk and others.

VISALIA, CAL.—Mt. Whitney Power & Electric Company, capital stock $5,000,000, by J. C. Hays, T. J. Broderick, F. G. Hamilton, H. T. Hays and A. C. Chickering.

COEUR d'ALENE, IDAHO.—Post Falls Land & Water Company; directors are Boyd Hamilton, J. L. Gunsau, A. D. Lundy, James A. McLane and Harry McLane; capital $350,000.

VISALIA, CAL.—Lindsay Incorporated Oil Company, capital stock $200,000, subscribed $32,000, by E. H. Howe, L. G. Stallings, H. A. Brisco, W. R. Flynn, A. P. Gomes, A. J. Perry, M. P. Thomas, L. S. Whittenden and F. J. Hilyard.

TRANSMISSION.

CHESAW, WASH.—James P. Blaine of the Apex Mining Company, has received orders to purchase a power plant for the mine here.

SALINAS, CAL.—The County Board of Supervisors has granted a franchise for a power line between Salinas and Monterey to the Monterey County Gas & Electric Company.

EVERETT, WASH.—Water power locations have been filed by B. Thomas of Seattle, on the Skykomish River near the confluence of the north and south forks and near Index and Salem.

RED BLUFF, CAL.—The Board of Supervisors has awarded a franchise asked for by the Sacramento Valley Power Company, giving it legal right to use the public highway for its poles and wires.

LOS ANGELES, CAL.—The Mexican Light & Power Company, which has a monopoly in Mexico City and supplies the El Oro mining district, has decided to build a branch transmission line to Pachuca and deliver current to the mines and the mills in that district.

IDAHO FALLS, IDAHO.—A. V. Scott of the Idaho Power & Transportation Company, announces that his company has acquired the St. Anthony water system. These holdings embrace plants at Rexburg, Sugar City and St. Anthony, together with the water power at the last named place for approximately $150,000. A number of improvements will be made.

BURBANK, WASH.—James D. Hodge of Seattle, president of the Burbank Power and Water Company, announces that contracts have been let for the construction of a new pipe line and distributing canal which will practically double the capacity of the plant at Five Mile rapids, on the Snake River, near Pasco. The contract was let to Otto Hansen of Kennewick and this with other work planned by the company will cost $50,000.

SAN BERNARDINO, CAL.—The City Council has passed an ordinance granting to the Southern California Edison Company a franchise to erect, construct, maintain and operate piers, masts, poles, etc, and to lay, maintain and operate wires, cables and other appliances for transmitting and conducting electricity under and over county roads, highways, etc., in the county of San Bernardino.

GRANGEVILLE, IDAHO.—Five million dollars is the stated capital of a company now being organized in Spokane to develop a power site on the Snake and Salmon rivers in central Idaho, 40 miles south of Grangeville, where A. W. Trine, 1815 Boone avenue, Spokane, and G. F. La Frenz of 1623 Spokane, have located a dam and site for a power plant. The project involves the boring of a tunnel of seven and a half miles through solid rock.

TELEPHONE AND TELEGRAPH.

PORTLAND, ORE.—The Home Telephone Company will erect three new exchanges on the East Side, and largely extend its system. Places where they are to be erected at are Sellwood, Mount Taber and St. Johns. The cost will be $100,000

SAN FRANCISCO, CAL.—In all probability the entire transpacific fleet of the Pacific Mail Steamship Company will be equipped with wireless apparatus, according to a statement authorized by R. P. Schwerin, vice-president and general manager.

PORTLAND, ORE.—The Pacific Radio Company is receiving bids for the construction of a steel tower 260 feet in height for a long distance wireless telephone station. Stations will also be erected in Tacoma, Everett and other cities on the Sound.

TACOMA, WASH.—For several weeks the Tacoma City Council has threatened to bring action against the Pacific Telephone & Telegraph Company to ascertain by friendly suit whether the company has a franchise to operate in Tacoma. The franchise of the old Sunset Telephone Company granted 20 years ago, has expired, but the company claims that when it agreed several years ago to lay certain wires underground, it was given an extension of franchise until 1915.

SAN DIEGO, CAL.—The Pacific Telephone & Telegraph Company is spending $75,000 in San Diego in extending conduit systems and aerials. They will thoroughly overhaul and rebuild lines in Coronado and La Jolla, and they have recently installed an addition to the switchboard consisting of 1000 answer jacks and 600 multiples. The San Diego Home Telephone Company recently changed hands, and are now operating under the following officers: Horace B. Day, President and Treasurer; Roy E. Thompson, Vice-President and Manager; E. R. Thompson, Secretary. They are planning to put in $50,000 in improvements, consisting of automatic switching apparatus extensions, etc.

ILLUMINATION.

FOREST GROVE, ORE.—The City Council has voted to accept the 10-year bid of A. Welch to furnish electric lights, beginning December 1st.

RIVERSIDE, CAL.—At a meeting of the Board of Public Utilities a year's contract for furnishing electric light globes to the city was awarded to the General Electric Company of Los Angeles.

LOS ANGELES, CAL.—An ordinance providing for ornamental lighting of Pico street from Main to Vermont has been passed by the council.

BILLINGS, MONT.—The Chamber of Commerce is interesting itself in the project of securing a gas plant for the city and reports that a number of firms are anxious to get into the field.

SAN FRANCISCO, CAL.—At the meeting of the Regents of the University of California a number of contracts were awarded. That for the lighting fixtures in the new University library was given to Thomas Day & Co. at $8350.

SANTA ROSA, CAL.—At its last session the Board of Supervisors advertised for sale the franchise applied for by A. Sbarboro and A. E. Sbarboro for an extension of the lines of the Cloverdale Lighting Company throughout northern Sonoma County. It is proposed to light several small towns and also supply power for a number of business enterprises.

BAKERSFIELD, CAL.—That a great gas belt, one capable of supplying the whole State of Californio with gas, exists along the low range of hills north of Midway and McKittrick, is becoming more and more evident with the extension of development work. The Crandall well on 10, the standard in 26, five miles away, and the old Fearless at McKittrick, miles further on to the west, demonstrate that the belt is continuous.

TRANSPORTATION.

BILLINGS, MONT.—The Eastern Montana Electric Railway Company has asked for a franchise.

SEATTLE, WASH.—The Seattle-Tacoma Short line will open offices in the Central building, in the near future and will soon award contracts for construction work.

EVERETT, WASH.—Work has been commenced by the Stone & Webster Company on the one story reinforced concrete power station for the Everett-Seattle interurban electric railway.

POMONA, CAL.—The City Trustees of Claremont have been asked to grant a franchise for the construction and maintenance of an electric street railway from Indian Hill through Claremont.

PRINEVILLE, ORE.—Arrangements for the survey of an electric railway from Opal City, a new townsite recently laid out between Trail Crossing and Culver road, to run to Prineville, have been made.

LONG BEACH, CAL.—The Pacific Electric Company will begin the work of four-tracking the main line between Watt and Dominguez as soon as the Daisy avenue extension of the Wilmington-Long Beach line is finished.

MEDFORD, ORE.—John Roberts Allen, president of the Pacific & Eastern, will apply at the next meeting of the City Council for a franchise in this city for an electric railroad. An application for a franchise will also be made in the other cities of the valley from Grants Pass to Ashland.

GUADALAJARA, MEX.—La Barca, one of the principal towns of this State will secure trolley cars through efforts of Fructuoso Castellanos and Louis Navarrete, who have formed a company to acquire horse car lines of that place, and have asked the State government for a concession for electric traction.

SALEM, ORE.—The Oregon Electric Railway has filed articles, showing the road plans an extension from Salem to Roseburg, a branch to leave the main line between Portland and Tualiatin, and operating to a point on Tillamook Bay; also a branch line from Albany extending to Cascadia; also a branch line paralleling the main only on the west side of the Willamette River, leaving the main line between Portland and Wilsonville.

SAN JOSE, CAL.—A number of the property holders of the Hyde Park tract met this week and organized for the purpose of securing an electric railroad franchise from Santa Clara to Luna Park and giving it away. J. L. Lawson was chosen chairman and Captain George H. Cooper, secretary of the meeting at which about 25 residents and property holders were present. If it possible to obtain the franchise it will be offered to and given to anyone who will build and operate an electric line upon it. The proposed route of the electric road would take almost a direct line from Santa Clara to Luna Park. Leaving the Alameda at Newhall street, it would run easterly to Spring, south on Spring to Hamline and east on Hamline to the Alviso road. From the Alviso road it would cut directly across the Phelan property to Twelfth street, travel along Twelfth for a short distance and turn into and out the Berryessa road. Representatives of the Phelan estate in this city have tentatively agreed to donate a right of way through the property from First street to Twelfth.

WATERWORKS.

SANTA CRUZ, CAL.—It has been ordered that four-inch water pipe be purchased for Storey street.

ABERDEEN, WASH.—The council has awarded to the Washington Pipe and Foundry Company the contract for furnishing 40,000 feet of wooden pipe.

GEORGETOWN, WASH.—An ordinance has been passed granting to the Georgetown Water Company the right to erect and operate waterworks in this city.

YUBA CITY, CAL.—The Hampton Hardware Company of Marysville has been awarded the contract for the installation of a pumping plant at the county hospital.

ENTERPRISE, ORE.—The City Recorder and Marshal have been instructed to figure the amounts and size of pipe needed and the Recorder has been instructed to order a carload of pipe.

BRAWLEY, CAL.—The Brawley Town & Improvement Company, with a capital of $200,000 will begin the development of the town of Weston. A hotel will be built and a water system installed.

RENTON, WASH.—The City Clerk has been authorized to ask for bids for supplying and laying of 6000 feet of ten-inch wooden water pipe from the reservoir to the city of Renton, at a cost of $35,000.

PORTLAND, ORE.—Plans and specifications for the proposed second pipe line to Bull Run River was ordered by the Water Board this week, with the instruction to Chief Engineer Clarke that they be prepared at the earliest possible date.

CENTRAL POINT, ORE.—At the City Council meeting last week the matter of the construction of a water system was discussed and Engineer Osgood of Medford was engaged as city engineer, the ordinance committee being instructed to prepare an ordinance covering the proposition as made by Mr. Osgood.

MARYSVILLE, CAL.—C. F. Aaron of the Yuba Dairy Company has stated that a deal has just been consummated whereby his company secures 267 acres of choice land in Sutter County. They will at once commence to improve this tract and plant it to alfalfa, irrigating it with two electrical pumping plants that will be installed.

SAN FRANCISCO, CAL.—The first step toward the construction of the first pumping station for the new fire-protection system has been taken by the Board of Works. It has approved the city engineer's plans for the plant, to be located at the corner of Second and Townsend streets and has asked the Supervisors to appropriate $400,000 to cover the eight contracts for the building and its equipment.